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# APPENDIX A

## West Nile Virus and West Nile Mosquitoes: An Overview

### Overview of West Nile Virus

West Nile virus is a disease that can be transmitted to humans by mosquitoes. It has been common in Africa, west Asia and the Middle East for decades. It first appeared in the US in 1999 in New York. It has since traveled westward across the country. It commonly starts in the spring and ends in mid-September. The West Nile virus is carried long distances by infected birds and then spread locally by mosquitoes that bite these birds. Infected mosquitoes can then bite and pass the virus to humans and animals, primarily birds and horses.

It is rare to catch this illness, and most infected people will not get sick or will have only mild symptoms. However, in rare cases, West Nile virus can be fatal. West Nile virus can cause encephalitis (inflammation of the brain) and/or meningitis (inflammation of the brain's lining). However, most infections are mild and symptoms include fever, headache, body aches, and occasionally include skin rashes and swollen lymph nodes. Symptoms generally appear 3 to 15 days after exposure. All residents of areas where West Nile virus activity has been confirmed could be at risk, but people over age 50 seem to be especially vulnerable to the severe forms of disease. In rare cases, it can be fatal. More severe infections may include headache, high fever, neck stiffness, stupor, disorientation, coma, tremors, muscle weakness, convulsions or paralysis. Persons with these symptoms need to seek medical attention immediately.

### Mosquito Species

CDC reports in the United States, West Nile virus is transmitted by infected mosquitoes, primarily members of the *Culex* species. However, the Center for Disease Control (CDC) reports 43 mosquito species that have been found in West Nile positive\* mosquito pools in the United States since 1999. Table 1 presents these data along with other data from Virginia and Portsmouth source broken out by species.

### Virginia Species

The accompanying CD (Attachment A) contains the “Virginia West Nile Virus Plan 2003, Appendix 4.A” which defines the known and suspected WN species in Virginia and delineate specifics about the locations, breeding environments and travel ranges for the various species. The “1995 Craney Island Mosquito Survey” (Rindfleisch, 1995) is also a good reference detailing information on the local species.

<b>Table A- 1 West Nile Virus Mosquito Species</b>						
CDC Listed WN Positives in pools in United States <sup>1</sup>		US WNV for years 2001-2002 <sup>2</sup>			Virginia Ranking <sup>4</sup>	Portsmouth <sup>5</sup>
		Ranking	WN Vector Competence	Vector Status <sup>3</sup>		
<i>Aedes</i>	<i>albopictus</i>	6	High	Bridge	6	✓
	<i>aegypti</i>	17	Moderate	Bridge		✓
	<i>cinereus</i>	19	Unknown	Bridge		
	<i>vexans</i>	5	Low	Bridge	8	✓
<i>Anopheles</i>	<i>barberi</i>	16	Unknown	Bridge		
	<i>atropo</i>					
	<i>crucians/bradleyi</i>					✓
	<i>punctipennis</i>	7	Unknown	Bridge		
	<i>quadrifasciatus</i>					✓
	<i>walkeri</i>	20	Unknown	Bridge		
<i>Coquillettidia</i>	<i>perturbans</i>	10	Low	Bridge		✓
<i>Culiseta</i>	<i>inornata</i>	22	Unknown	Bridge		
	<i>melanura</i>	9	Unknown	Primary		
<i>Culex</i>	<i>erraticus</i>					
	<i>quinquefasciatus</i>					
	<i>tarsalis</i>					
	<i>nigripalpus</i>					
	<i>restuans</i>	2	Moderate	Primary	2	
	<i>territans</i>	21	Unknown	Unknown		
	<i>pipiens</i>	1	Moderate	Primary & Bridge	1	✓
	<i>salinarius</i>	3	High	Primary & Bridge	3	✓
<i>Deinocerites</i>	<i>cancer</i>					
<i>Ochlerotatus</i>	<i>atropalpus</i>				7	
	<i>cantator</i>	24	Unknown	Bridge		
	<i>infirmatus</i>					
	<i>solicitans</i>	12	Moderate	Bridge	9	✓
	<i>taeniorhynchus</i>	13	Low	Bridge		✓
	<i>atlanticus</i>	23	Unknown	Bridge		
	<i>dorsalis</i>					
	<i>japonicus</i>	8	High	Bridge	5	
	<i>sticticus</i>					
	<i>triseriatus</i>	4	Moderate	Bridge	4	
	<i>canadensis</i>	14	Unknown	Bridge		
	<i>fitchii</i>					
	<i>provocans</i>					
	<i>stimulans</i>					
	<i>trivittatus</i>	11	Unknown	Bridge		
<i>Orthopodomyia</i>	<i>signifera</i>	18	Unknown	Unknown		
<i>Psorophora</i>	<i>ciliata</i>	25	Unknown	Bridge		
	<i>howardii</i>					
	<i>columbiae</i>	15	Unknown	Bridge		✓
	<i>ferox</i>					✓
<i>Uranotaenia</i>	<i>sapphirina</i>	26	Unknown	Unknown		

1 - CDC Website, data were obtained by CDC field investigations or were reported by state surveillance programs to CDC ArboNet as of 08/23/03.

2 - Field collected mosquito species found to be carrying West Nile virus (WNV) in the United States in 2001 and 2002 (carrying WNV does not necessarily mean that the mosquito was infected with, or had the ability to transmit the virus while feeding).

3 - Primary vectors feed on birds and maintain WNV in bird population; Bridge vectors feed on numerous animal species including horses, humans and birds and serve as a bridge for the virus to move from bird to mammal.

The “West Nile Virus and other Mosquito Borne Viruses in Virginia in 2003”, report to the 25<sup>th</sup> Biennial State Public Health Vector Control Conference, February 2004 by Dr. David N. Gaines, (Public Health Entomologist, Virginia Department of Health, Office of Epidemiology) reports the following WNV confirmations for 2003:

**Table A-2: WNV Positive Mosquito Species in Virginia in 2003**

<b>Mosquito Species</b>	<b>Positive Pools</b>	<b>Mosquitoes Tested</b>	<b>Number Tested per Positive</b>
<i>Culex pipiens</i>	285	35,067	123
<i>Culex restuans</i>	72	20,364	282
<i>Culex salinarius</i>	21	59,545	2,835
<i>Culiseta melanura</i>	20	68,200	3,410
<i>Culex spp.</i>	18	4,353	241
<i>Culex pipiens/restuans</i>	9	757	84
<i>Aedes albopictus</i>	4	9,061	2,265
<i>Aedes vexans</i>	2	24,188	12,094
<i>Culex erraticus</i>	1	2,639	2,639

Trends based on Virginia data were presented in the same report and the conclusions from the report are:

- WNV has not spread across Virginia as quickly as in other more northern states, but the 2003 season showed a dramatic increase in the distribution of WNV over its 2002 distribution
- Although WNV may be found over large areas of the state, its activity appears to be focal or clustered (localized) in most areas.
- Urban areas appear to have more intense WNV activity, partly because there are more people to report dead birds, or become sick themselves, but also because urban storm sewer systems and an abundance of containers provide a good breeding ground for *Culex pipiens*.
- The early occurrence of WNV infected birds in the 2002 and 2003 seasons indicated localities where there was greater potential for occurrence of human cases.
- In 2002 and 2003, human cases were more likely to live near where early clusters of WNV infected birds occurred.
- Human cases rarely occurred where no early birds had been found, but there were many areas where heavy, early WNV activity was seen in birds, but no local human cases occurred.
- WNV infected birds are good early indicators of WNV activity, but good mosquito surveillance can also provide a good early warning system.

- In areas where human cases occurred, bird surveillance indicated WNV activity from 6 to 9 weeks before the first human case and mosquito surveillance indicated WNV activity from 2 to 7 weeks in advance.
- Human cases typically occurred during, or just after the first big peak (increase) in the number of infected *Culex pipiens*.
- *Culiseta melanura* mosquitoes may serve as a good indicator for WNV activity, but *Culex pipiens* are a much more sensitive species to monitor because very few have to be tested to yield WNV positives.
- The use of properly baited gravid traps to detect *Culex pipiens* mosquitoes is the most effective method of mosquito surveillance for WNV.
- WNV infection in horses indicates local WNV activity, but horses do not serve as good sentinels because they usually get WNV at the same time or later in the season than most humans do.

## **APPENDIX B**

### **CORPS OF ENGINEERS MOSQUITO CONTROL PROGRAMS IN THE MIDDLE ATLANTIC COASTAL REGION**

<b>Corps District: Philadelphia</b>	<b>CDFs:</b> Along the Delaware River Main Channel to the Sea  Located in Salem County, NJ																						
<b>District Contacts:</b>  Tom Groff (PM, Operations) 215-656-6738																							
<b>Contractor Contacts:</b>  State of New Jersey Department of Environmental Protection Office of Mosquito Control Coordination Bob Kent, Administrator 609-292-3349  <i>Unable to reach Kent after numerous phone calls</i>	<table border="1"> <thead> <tr> <th>Name</th> <th>Size (acres)</th> <th>Ownership</th> </tr> </thead> <tbody> <tr> <td>Pendricktown</td> <td>N-560, S-522</td> <td>Federal</td> </tr> <tr> <td>Kilcohook Fill</td> <td>1234</td> <td>Federal</td> </tr> <tr> <td>Penn Neck</td> <td>322</td> <td>Federal</td> </tr> <tr> <td>Fort Mott</td> <td></td> <td>Federal</td> </tr> <tr> <td>Oldnus</td> <td>180</td> <td>Federal</td> </tr> <tr> <td>Pennsgrove</td> <td></td> <td>Leased to F&amp;W</td> </tr> </tbody> </table>	Name	Size (acres)	Ownership	Pendricktown	N-560, S-522	Federal	Kilcohook Fill	1234	Federal	Penn Neck	322	Federal	Fort Mott		Federal	Oldnus	180	Federal	Pennsgrove		Leased to F&W	
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Fort Mott		Federal																					
Oldnus	180	Federal																					
Pennsgrove		Leased to F&W																					
<b>Costs Information:</b>  CY 2002      \$69,564.12 for 2817 acres																							
<b>Chemicals:</b>  CY 2002 Aerial Application of Abate 2BG																							
<b>Procedures:</b>  Grant rights of entry to State of New Jersey for surveillance activities and pesticide applications.           No Environmental Assessment																							
<b>Attachments:</b> Contract & Invoice, State of NJ, with scope and 1986 protocol designed by Dr. Al Cofrancesco, WES (paper copy only)																							

<b>Corps District: Baltimore</b>	<b>CDFs:</b>													
<b>District Contacts:</b>  Woody Francis, Biologist, Eastern Shore, Permits Section 410-962-5689	Coastal CDFs Located on Chesapeake Bay  <table border="1" data-bbox="894 384 1511 636"> <thead> <tr> <th>Name</th> <th>Size (acres)</th> <th>Ownership</th> </tr> </thead> <tbody> <tr> <td>Poplar Island</td> <td>1100</td> <td>Co-owned State &amp; Federal</td> </tr> <tr> <td>Hart Miller Island</td> <td>1100</td> <td>State</td> </tr> <tr> <td>Cox Creek</td> <td></td> <td>State</td> </tr> </tbody> </table>		Name	Size (acres)	Ownership	Poplar Island	1100	Co-owned State & Federal	Hart Miller Island	1100	State	Cox Creek		State
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Hart Miller Island	1100	State												
Cox Creek		State												
<b>Contractor Contacts:</b>  State of Maryland Department of Agriculture Office of Plant Industries and Pest Management Mosquito Control Section Cyrus R. Lesser, Chief 410-841-5870 or 543-6626 <a href="http://www.mda.state.md.us">http://www.mda.state.md.us</a>  Maryland Environmental Services Hart Miller Island Operations Jennifer Harlan 410-974-7261	<b>Costs Information:</b>  No Cost to the Baltimore District  <b>Chemicals:</b> Aerial Application: <u>Larvicides:</u> Methoprene-liquid from fixed-wing Methoprene -granules from helicopter <u>Adulticide:</u> Trumpet EC													
<b>Procedures:</b> There are no strictly federally owned large Corps CDFs in the Baltimore District MD Dept. of Ag. Performs larvae and adult surveillance and WNV monitoring and testing. The operations at Poplar and Hart Miller Island (HMI) are most similar to conditions at Craney Island. There is no larvae or adult surveillance on Polar or Hart Miller Islands. MES performs ditching for crust management and dewatering at HMI Some mosquito-eating minnows exist naturally at HMI The operators at Poplar and HMI wait until the mosquitoes are on the wing, they then call the MD Dept. of Ag. and Trumpet is applied by fixed-wing aircraft. MES prefers that larvicides not be applied for fear of killing the non-target species. <u>T&amp;E Species</u> – Bald Eagle, Least and Common Terns <u>No Environmental Assessment</u> <u>Phragmites Control:</u> Spray liquid Rodeo™ in the Fall after all other plants have gone dormant; follow in the Spring with burning to reduce the mat; then seed with a State-approved wetland mix to reduce emergence														
<b>Attachments:</b> No attachments – General MD State Mosquito Control Program on the web <a href="http://www.mda.state.md.us">http://www.mda.state.md.us</a>														

<b>Corps District: Wilmington</b>	<b>CDFs:</b>								
<b>District Contacts:</b> Howard Varnum 910-251-4411	Small Coastal CDFs on AICWW And Wilmington Harbor CDF								
<b>Contractor Contacts:</b>  Contracts with four county Mosquito Control agencies: Pender, Onslow, New Hanover and Brunswick  Brunswick County Mosquito Control Jeff Brown 910-253-2515 ext. 2508 Eagle Island 880 acres, 40 other CDFs most 1-23 acres  Pender and Onslow Counties have 10-12 CDFs (less than 55 acres total) with easements to hand apply granular larvicides	<table border="1"> <tr> <th>Name</th> <th>Size (acres)</th> <th>Ownership</th> </tr> <tr> <td>Eagle Island</td> <td>880</td> <td>Federal</td> </tr> </table>	Name	Size (acres)	Ownership	Eagle Island	880	Federal		
	Name	Size (acres)	Ownership						
	Eagle Island	880	Federal						
<b>Costs Information:</b> None Provided									
<b>Chemicals:</b> <u>Larvicides:</u> B.t.i. by hand or granules from helicopter <u>Adulticide:</u> Trumpet EC									
<b>Procedures:</b> Responsibility at Eagle Island (large COE CDF) is shared by Brunswick and New Hanover Counties. Brunswick provided the information on the Mosquito efforts there. C.R. Lee (OA System) , along time dredged material management consultant to Wilmington District, interviewed Varnum regarding the activities at Eagle Island.  <u>Eagle Island:</u> <ul style="list-style-type: none"> <li>• Short targeted meeting among Mos. Control agencies and the Corps, to exchange trends and lessons learned.</li> <li>• Inspections and larvae surveillance atleast monthly or after each rainfall event</li> <li>• Water Management – dewater, connect isolate pools, allow minnows and fish pathways</li> <li>• Use Granular Bti – very effective – apply by hand or helicopter</li> <li>• Very minimal aerial liquid application of adulticides</li> </ul> The attached reference documents describe in detail the aggressive water management program and importance of larvicide surveillance <u>T&amp;E Species</u> – Migratory birds and alligators <u>No Environmental Assessment</u> <u>Phragmites Control:</u> Mow dikes and spray or wipe liquid Rodeo™									
<b>Attachments:</b> <ul style="list-style-type: none"> <li>• Summary Description by Dick Lee.</li> <li>• Progress Report for Mosquito Control on Eagle Island for 1996-1998</li> <li>• Management Recommendations for Eagle Island Confined Disposal facility Mosquito Surveillance and Control (1996)</li> <li>• 2000 Wilmington Harbor Interagency Work Group Report</li> </ul>									

## Mosquito Control at USACE Confined Disposal Facilities (by C.R. Lee, Ph.D.)

The US Army Corps of Engineers (USACE) Wilmington District is an excellent example of accomplishing mosquito control at their dredged material confined disposal facilities (CDFs). The procedures and methods used should be applicable to all Districts that are responsible for the maintenance of CDFs and the control of mosquitoes. The coordinator and point of contact for the Wilmington District CDF management is Mr. Howard Varnam, (910) 251- 4411. Mr. Varnam has established annual USACE contracts with the Operations Services Departments for Brunswick, New Hanover, Pender, and Onslow Counties in which CDFs are located. Sole source contracts have been established with authority up to \$100,000.00 for each CDF for each county. An example of a scope of work prepared by the Wilmington District for Brunswick County is attached (Attachment 1). Two contracts were awarded: one for Eagle Island not to exceed \$50,000.00 and one for Intracoastal Waterway island CDFs not to exceed \$75,000.00. Since Eagle Island also lies in New Hanover County, a contract with New Hanover County was also established. Both counties jointly manage mosquito control for that CDF. Close coordination is maintained among dredging contractors and County mosquito control personnel to schedule dredging/disposal operations and mosquito control management activities.

Under these contracts, Brunswick County controls mosquito production at the CDFs using Integrated Pest Management (IPM) including physical, chemical and biological methods. Physical methods include surface ditching and drainage and weir board control. Chemical control includes the application of mosquito adulticides and larvicides. Biological methods include mosquito larva-eating fish or minnows.

Eagle Island CDF is located on a 1,473 acre tract owned by the USACE (Figure 1). The property was acquired from the United States Marine Commission, which had condemned the property in the 1940's for use as part of a ship storage facility. The boundaries are defined by the Brunswick River on the west side, Cape Fear River on the east side and creeks on the north side. Eagle Island CDF is approximately 880 acres of diked uplands and divided into three cells. Cell 1, Cell 2, and Cell 3 are approximately 220, 260 and 260 acres, respectively. Annual maintenance dredging amounts to approximately 1,000,000. cubic yards of dredged material. Since the Wilmington Harbor is presently being deepened and widened, an addition 6 million cubic yards of new work dredged material is being placed in the CDF. To accomplish this, a program of dike raising is being implemented.

Management of Eagle Island CDF consists of three process stages: one active cell receiving dredged material, one drying cell, and one completely dried cell. Each cell is managed independently for mosquito control.

In order to manage mosquitoes in each cell, the ecology of the mosquito needs to be considered. The following discussion has been extracted from the attached "scope of work". The predominate mosquito species at Eagle Island are *Ochlerotatus taeniorhynchus* and *Oc. sollicitans*. The critical breeding season for these species is from mid-March through October, with critical management and control months being July and September. The life cycle of these floodwater mosquito species requires a dry period when the eggs are conditioned, followed by a wet flooded period when the eggs hatch into larva. The larva develop through several stages and emerge as adults in the floodwater. When the disposal area starts to dry out, as required for dredged material management, the mosquito breeding potential increases. When the dredged material and the eggs dry out, the next flooding from rainfall "triggers" the eggs to hatch.

Breeding areas are associated with low spots of standing water with cracked clay or fine textured dredged material, which holds water in each crack. Frequent rainfall often leads to repeated production of mosquitoes as the habitat dries, cracks and floods. Under optimum conditions, mosquitoes emerge from the dredged material disposal sites usually within 5-10 days after a rain fall event. Consequently, broods of salt marsh mosquitoes are produced after rainfall events. Once a brood of mosquitoes is “triggered” by rainfall and the adult stage has been reached, female salt marsh mosquitoes disperse into the surrounding areas. After they find a blood meal, they return to the same general area to lay eggs, and the cycle occurs again. All eggs do not hatch every time it floods, so there are always eggs to hatch when another flooding occurs. The development from newly hatched larva to adult requires only 5 or 6 days in the summer. Females may disperse up to 10 miles from the breeding sites.

Based on past surveillance, mosquito-breeding areas on the dredged disposal islands are found both within the interior portion of the dike as well as around the outer rim of the dike. Water that seeps from the disposal area through the wall of the dike into surrounding disturbed areas produces mosquito-breeding habitat in the borrow pits outside the base of the cell. Seepage water from inside the dike trapped in low areas between the existing dike wall and an old remnant dike provides ideal mosquito breeding habitat.

Based on the ecology of the mosquito discussed above, mosquito management and control are designed for each of the three cells. For example, the active cell stage, receiving dredged material, is maintained with a minimum of a two foot surface layer of water using the weir boards (Figures 2 and 3). Ponded water over large areas within the cell reduces drying and cracking of the deposited material and creates improved conditions for mosquito-eating fish (*Gambusia affinis*) populations in the cell. After the disposal of dredged material is complete, the cell then undergoes the ditching, draining and dewatering process stage. During this process, weir boards are removed and surface ditches are established with ditching equipment to drain surface water and rainfall (Figures 4 and 5). Mosquito-eating minnows are placed in the ditches. To provide access, an interior toe-dike ditch is established continuous around the cell to have a positive drainage to allow for the movement of minnows into the areas of standing water. During the drainage process, if standing water develops in low spots within the cell and minnow populations are absent, hand stocking of these areas with minnows is accomplished. Some hand ditching may be required to connect isolated depressions. In addition, EPA approved granular larvicides, such as Alacide, are applied in breeding ponds with active larval populations. Swamp buggies are used to reach these isolated low ponded areas. In the last process stage of the completely dried cell, drainage ditches are maintained to quickly drain off any rainfall to the weir (Figures 6 and 7). Mosquito-eating minnows are placed in the drainage ditches to control mosquitoes in the ditches.

The County maintains a holding pond for the mosquito-eating fish outside the dike for easy access to minnows when required for placement within the cells.

The County Mosquito Control Program applies limited EPA approved ultra low volume (ULV) treatment in the identified 3 mile impact zone around the dredged material disposal islands when adult mosquito populations warrant treatment.

Weed control for *Phragmites* has not been an active effort at Eagle Island. The *Phragmites* actually enhances the filtering of the dredged material slurry during the active filling stage of a cell. During the ditching and draining stage, *Phragmites* tends to grow and dewater the dredged material. During the final dried stage, the *Phragmites* becomes more of a problem, especially if dredged material is used in beneficial ways. Dike raising activities have scrapped

the above ground portions of *Phragmites* into piles to be burned or composted. Burning creates air quality concerns. Composted *Phragmites* has been used as a source of cellulose for the manufacture of wetland substrate for constructed wetlands (Burchell, 2003 and Burchell et al. 2004). *Phragmites* did not regrow from the compost even under wetland conditions. The predominate regrowth of *Phragmites* results from underground rhizomes. These rhizomes must be killed and eliminated to stop the growth of *Phragmites*. It would be advantageous at this final dried stage of dredged material management to apply weed control methods to eliminate *Phragmites* so the removal of dredged material for beneficial uses will not spread the weed to other areas. A wiping application of Round-Up or Rodeo herbicide has been demonstrated at Eagle Island (Lee, 2000) and has given excellent control. The *Phragmites* free dredged material was planned to be used to manufacture topsoil for landscaping according to Recycled Soil Manufacturing Technology (RSMT).

#### Literature Cited:

Burchell II, M. R. 2003 Practices to Reduce Nitrate-Nitrogen Losses from Drained Agricultural Lands. Ph.D. Dissertation. Biological and Agricultural Engineering Department, North Carolina State University, Raleigh, NC.

Burchell, II, M. R., R. W. Skaggs, C. R. Lee, S. Broome, G. M. Chescheir and J. Osborne 2004. The Role of Substrate Organic Matter in Improving Nitrate Removal Efficiency in Surface-Flow Constructed Wetlands. Journal of Environmental Quality (In press).

Lee, C. R. 2000. Implementation Guidance for the Control of Undesirable Vegetation on Dredged Material. DOER Technical Notes Collection (ERDC-TN-DOER-C20), U. S. Army Engineer Research and Development Center, Vicksburg, MS [www.wes.army.mil/DOTS/DOER/](http://www.wes.army.mil/DOTS/DOER/).

# **Progress Report for Mosquito Control on Eagle Island for 1996-1998 by Brunswick and New Hanover Counties and the U.S. Army Corps of Engineers Wilmington District.**

## **I. Background Information**

The Eagle Island Confined Disposal Facility (CDF) is an upland diked disposal island situated in Brunswick County and bordering New Hanover County. Eagle Island is situated on marsh with an original elevation of approximately 4 feet, with a foundation of soft deposits extending down to approximately 38 feet. The site is now diked to an elevation of about 20 feet. Approximately 1 million cubic yards of maintenance dredged material, consisting of predominately silts and clays, is dredged from the river and pumped to Eagle Island annually. Much of the interior portion of each cell is covered with a dense growth of *Phragmites australis* and other vegetation.

A cross dike, which has been constructed across the CDF, subdivides the site into two major upland diked disposal areas or cells for management purposes. The south cell covers approximately 300 acres. The north cell covers approximately 650 acres. Each cell is used for two years. Discharge of dredged material is then cycled to the next cell. The inactive cell is allowed to dry out by de-watering with dike construction and ditching prior to future use.

## **II. Mosquito Ecology on Eagle Island - 1995**

Documentation from previous surveillance of the island indicates that pest mosquitoes breeding on the island consist primarily of two salt marsh mosquito species *Aedes taeniorhynchus* and *Ae. sollicitans*). Both species, along with several others, have been documented through collection and identification on Eagle Island. The critical breeding season for these species is from mid-March through October, with the critical management and control periods being March, July and September.

The life cycle of these floodwater mosquito species requires a conditioning period where the eggs are allowed to dry after being laid followed by a wet flooded period where the eggs then hatch into larva. The mosquitoes develop through four larval stages and a pupal stage before emerging as adults. As many as 15-20 broods of salt marsh mosquitoes may be produced each season. Each female mosquito deposits 100-200 desiccant resistant eggs on the sides of the cracks and crevices in the dredged material that can remain viable for years. Not all the mosquito eggs hatch every time it rains, so there is always a viable egg bank waiting to hatch when the next rainfall event occurs. The mosquito development from egg to adult requires only five or six days in the summer.

Mosquito breeding areas inside the dike are associated with low spots of intermittent water with cracked clay material, where water fluctuates in the crack network with each rainfall event. Frequent rainfall events often causes multiple broods of mosquitoes as the habitat dries, cracks, and floods repeatedly. Once a brood is “triggered” by a rainfall event and the adult stage is reached, female salt marsh mosquitoes mate and then disperse into the surrounding areas to find a blood meal. Some of the mosquitoes remain in the area to lay eggs and the cycle occurs again. Early in the mosquito season, populations are small. With each successive uncontrolled brood, the mosquito population increases exponentially. Based on past surveillance, mosquito-breeding areas on the Eagle Island CDF are found both within the interior portion of each cell as well as around the outer rim of the dike. Seepage water from inside the dike trapped in low areas between the existing dike wall and an old remnant dike provides ideal mosquito breeding habitat.

## **III. Successes of the 1996-98 seasons**

### **A. Surveillance Data Collected**

Surveillance data collected for 1996-1998 on *Aedes sollicitans* and *Aedes taeniorhynchus* can be found graphically at the end of this report. The Brunswick County graphs represent a historic larval perspective of the two species. Larval collections identify monthly population trends and individual site types for mosquito larva production. The New Hanover County graphs represent weekly light trap data collected for the two species in New Hanover County for 1997 and 1998. They also represent the adult population longevity and help to identify environmental factors influencing adult salt marsh mosquito production. Maintaining both a historical larval database and historical adult collections helps the two counties anticipate salt marsh mosquito production on Eagle Island. Knowing when and where to focus control efforts enables the two counties to implement a dynamic plan that is flexible and adjusts itself based on population data and environmental variables found on the island.

**Habitat Preference Information Collected 1996-98.** Ovi-position by the two salt marsh species on the island seems to be related to specific site types both inside and outside the dike. *Aedes sollicitans* is found in the spring and fall in shallow, sparsely vegetated areas of the island. While *Aedes taeniorhynchus* can be found during the peak summer months in deeper water and more heavily shaded areas. There is some overlap by the two species with respect to seasonality and larval habitat. For example, in 1997 at the southern tip of the south cell (outside the dike in a borrow pit), *Ae. sollicitans* were found in the spring and fall while *Ae. taeniorhynchus* was found in the summer months. The variables appear to be related to temperature, water level and seasonal niche preference of each species. The challenge on Eagle Island remains locating and addressing these habitat types. Eagle Island is not an environment that stabilizes over time. Every disposal/construction cycle removes and creates new mosquito habitat. If these new sites are identified and manipulated soon after a disposal/construction cycle, mosquito populations should remain small and adult dispersion will remain limited.

## **B. The North Cell**

In 1996 and 1997, the north cell was controlled using water management. Weir boards were put into the three spillways and the water level was increased in the dike. Approximately 1/3 of the north cell remained underwater and *Gambusia* minnows were put into the saturated area. The remaining 2/3 of the cell stayed dry. A perimeter ditch was dug around the north tip of the cell to connect large depressions within the cell. This facilitated minnow movement throughout the potential breeding areas of cell. Each time the water level increased due to seasonal rainfall, the minnow population dispersed into the wet/dry transition area and preyed on any emergent larval populations. As the water level receded the minnow population receded. An area of concern was the transition area between the submerged and terrestrial area in the middle of the dike. The foliage in the interior of the cell is densely covered with *Phragmites* reed and willow trees. Multiple foot surveillance trips were made to this transition area each year to determine the mosquito production. Landing counts in the field did identify a small amount of adult mosquito production.

Increasing the submerged area in the north cell increased the aquatic predator habitat. The populations of adult dragonflies and predacious aquatic insects increased notably on the island in 1997 and 1998. The *Aedes* species of mosquito targeted for control ovi-positioned directly on the ground, near areas of intermittent water. The *Gambusia* minnows and other insect predators helped to keep the breeding in the intermittent area in check as the water level fluctuated into these intermittent areas. Overall, water management in the north cell decreased mosquito habitat and increased predator habitat and provided a mechanism to control the transition area between the two.

The control focus on the north cell changed in 1998. The Corps of Engineers required a dry-down of the north cell so dike construction could begin. Weir boards from the spillways were removed one at a time. The weir boards were pulled slowly so the water leaving the dike did not adversely affect the Brunswick River water quality. Close contact with the COE was maintained throughout this process. At the same time the water level was being reduced, New Hanover County began creating a perimeter ditch from the

wet/dry transition toward the weirs. Spoil material from the ditching process was placed on the edge of the road facing the inside of the dike and could be used for future dike construction. The bulk of the water was removed from the north cell prior to any seasonal mosquito activity (January-March). As more weir boards were removed and the water level inside the dike lowered, the perimeter ditch was excavated deeper to maintain positive drainage. When the mosquito season arrived in 1998, most the surface water was gone from the north cell and mosquito production was minimal. The timing of water reduction is critical to the success of this effort. Initiating drainage measures during the mosquito season (March-September) could be detrimental to this process. To maximize control measures, dry-down should be initiated after the peak mosquito season (October), and be well underway before the spring season begins in March.

### **C. The South Cell**

In 1996 the south cell was in a transition phase. The dry-down, in preparation for dike construction, had been initiated. Unfortunately, information pertaining to larval mosquito production in the south cell had not been investigated. Most control efforts were initiated from the dike. There were three mosquito breeding sites in the south cell and two productive sites outside the cell at the base of the dike. Larval surveillance had located two of the five sites. The mosquito production at these two sites was vicariously controlled using hand applied Bti. Truck mounted ULV chemical applications from the dike road were also used to manage the emergent adult populations at the other three sites. Attempting to identify and control mosquito ovi-position sites without preseason base-line surveillance or an understanding the dynamic of the dredge spoil island habitat is difficult at best. The initial larval surveillance had not been comprehensive. Communication between agencies involved prior to 1996 was limited. The south cell would be the learning curve we all needed to effectively control the larval mosquito populations.

We were able to keep the populations confined to Eagle Island for the most part in 1996. For the few incidents when the mosquito population migrated; phone calls were made and both counties responded with truck mounted ULV's in the impact areas of their counties. Hurricane Bertha struck the coast of Southeast North Carolina in July 1996 and aerial surveillance of the island was conducted using a video camera. The suspected breeding areas of the south cell were holding water and these sites were treated using a helicopter. Hurricane Fran hit in September 1996. Eagle Island did not experience a brood of mosquitoes after hurricane Fran.

In 1997, efforts were focused on source reduction. The south cell was de-watered by excavating a perimeter ditch between weirs and connecting the low areas by hand digging slot-ditches to the new perimeter ditch. Additionally, identification of potential "seed holes" during the winter months (when the groundwater levels were high) helped to focus larval control efforts during the spring control period. A "seed hole" is a site utilized by salt marsh mosquitoes on a regular basis. Early season (March-April) larviciding of these seed holes was the key to controlling the south cell in 1997. Controlling seed holes limits the early adult population size. Limiting the size of the adult population around the seed hole using truck mounted ULV applications limits the amount of adult dispersion from the seed hole area. It seems the adult mosquito population around the seed hole has to reach a certain threshold before dispersion to surrounding areas will occur.

In 1998, dike construction in the south cell continued. Surveillance on the cell at this juncture was critical. Potential breeding areas were identified during construction by locating the deepest excavations in the cell and anticipating the direction, flow and settling of the dredge material from the dredge pipe to spill-over at the weir. By identifying and documenting the potential breeding sites on a map, mosquito control personnel are able to focus control efforts at those depressions left after a dredge cycle. The primary control method utilized inside the dike in 1998 was the transportation and colonization of minnow populations into excavations created

by dike construction. Additionally, larvicide applications outside the dike were used to minimize seed hole production.

#### **D. Outside the Dike**

January 1996 provided the surveillance foundation used to define an overall strategy for controlling Eagle Island. The field surveillance of Eagle Island was performed to provide insight on the breeding habitats of mosquitoes outside the island dike. Specific variables were used to determine locations of rainfall and/or tidal influence on potential mosquito habitat. The variables are plant transitions, degree of tidal inundation, and existing standing water.

The vegetation of Eagle Island is composed mainly of *Phragmites australis*. *Phragmites* can be found growing within both dredge cells as well as the outside perimeter of Eagle Island. *Phragmites* is a well-known indicator of recently disturbed habitats and is able to grow extremely fast and, as a result, out-compete other plant species. *Phragmites* is somewhat tolerant to water inundation and drought, as well as changes in water salinity. It can be found growing in dense stands in dry soils. The overall growth and health of the plant are affected by water inundation. For example, in wetter areas *Phragmites* produces less dense seed heads than those of plants growing in drier areas. The height and density of the plants can also be a determining feature. Plants growing in wetter soils tend to be smaller in stature and are less dense than plants growing in drier soils.

Other plant species were used to determine tidal influence, standing water, and potential breeding sites on Eagle Island. These plant species are cattails, *Typha angustifolia*; tall salt marsh cordgrass, *Spartina cynosuroides*; sedges, *Scirpus* sp.; black needle rush, *Juncus roemerianus*; and saw grass, *Cladium jamaicense*. The identification of various tree species helped to determine intermittently flooded sites and include red maple, *Acer rubrum*; groundsel, *Baccharis halimifolia*; wax myrtle, *Myrica cerifera*; eastern red cedar, *Juniperous virginiana*, yaupon, *Ilex vomitoria*; and bald cypress, *Taxodium distichum*.

Foliage transitions were a vital aspect of this survey. Patterns in plant zonation, tidal channels and tidal influence were determined. This was applied to aid in the determination of nontidal breeding sites. The plant zonation on Eagle Island typically occurred in the following order (from driest to wettest); not all species were present in every location studied: *Phragmites australis* (6-15 feet tall; tan in color), *Spartina cynosuroides* (4-6 feet tall; gold in color), *Scirpus* sp. (2 feet tall; yellow to brown in color), *Typha latifolia* and *Typha angustifolia* (3 to 4 feet tall; silver in color), *Cladium jamaicense* (2 feet tall; green to yellow in color), *Juncus roemerianus* (3 feet tall; green to brown in color). The colors associated with the plant species listed above are typical for winter identification.

An additional feature on Eagle Island that can aid in identifying mosquito-breeding sites is the high tide/wrack line. Mosquitoes will not typically breed in areas that are regularly affected by the tides because constant tidal flushing does not provide suitable habitat for egg deposition. However, egg deposition and larval success may be found in natural depressions and disturbed areas slightly above or below the wrack line. Wrack deposited by the tide can be a visual cue for determining the upper reaches of the tide. When the mean tide line is established at a location, the nonbreeding site can be recorded and excluded from future surveillance.

Disturbed areas outside the dike at its base can also provide mosquito-breeding habitat. These seed holes may be the source of the initial adult populations that “seed” mosquito eggs onto the freshly pumped dredge material inside the dike. For example, borrow pits created by dike construction, depressions left between the toe of the old dike and the newer dike provide mosquito habitat. Trenches dug to provide material for dike construction trap and hold water. Old drainage pipes create isolated pockets of standing water at their base outside the dike. Finding and recording the locations of such sites was the goal of the winter surveillance. Representative breeding sites were monitored during the 1996-1998 mosquito

seasons to provide insight to the reproductive habits of *Aedes taeniorhynchus* and *Aedes sollicitans*. As a result, a more effective larval control of salt marsh mosquitoes outside the dike can be pursued.

#### **IV. Future Considerations**

The subdivision of the existing north cell into two cells is currently under construction (Figure 3). The south cell is receiving dredge material in 1998 and will remain flooded in 1999 until dredging is initiated. The following are a few things that need to be addressed about the water removal efforts.

1. The spoil material inside the north cell was deposited from multiple dredge cycles. This may affect the stability of the spoil material inside the dike. Multiple layers of material over time may increase the overall stability while a single layer may not be as stable. How long will it take to dry out the dike on the south cell after the final pumping cycle? Can it be done? Can we initiate perimeter ditch construction to facilitate drainage between pump cycles?
2. Will this same process work in a wetter season (1998 was an extremely dry year)?
3. Salt marsh mosquito production was very mild in 1998. Can these mosquito populations be managed effectively even with larger surrounding mosquito populations? The south cell should provide some of these answers in 1999.
4. This Integrated Pest Management program should work for at least the next six years and be thoroughly documented before it is considered effective.
5. Movement inside the dike after a dredge cycle is still a problem. Will we need to go in the cell using these techniques?
6. Mosquito light trap data and complete documentation should be in place on the island to document yearly trends and identify problem areas. Stations should be identified and maintained on a weekly basis from March through October.
7. Seed hole identification and management should be documented on a map of the island from year to year.
8. New Hanover County is designing a plan to create a toe-dike inside the dike to facilitate excavation of a perimeter ditch for COE consideration. This will facilitate positive drainage after construction of a new dike. A toe-dike inside the base of the dike will move the perimeter ditch 30 feet into the cell increasing the stability of the dike and facilitating future dike drainage and construction.
9. An emergency control plan needs to be defined. The parameters of its implementation also need to be considered.

#### **V. Other Dredge Disposal Areas**

Because mosquito breeding occurs in many areas where dredge disposal is contained, similar to Eagle Island, the state of North Carolina recommends that all dredged material disposal facilities in the Wilmington District be considered potential breeding sites. All problem sites should be surveyed for breeding and corrective measures planned. Many of these control measures identified for Eagle Island will work on the smaller intercoastal waterway dredge spoil islands. Brunswick and New Hanover Counties have already implemented these techniques on their smaller islands.

## **Management Recommendations for Eagle Island Confined Disposal facility Mosquito surveillance and Control Brunswick and New Hanover Counties (1996)**

**1. Eagle Island Confined Disposal Facility (CDF).** The Eagle Island CDF is an upland diked disposal island situated in Brunswick County and bordering New Hanover County. Eagle Island is situated on marsh with an original elevation of approximately + 4 feet, with a foundation of soft deposits extending down to approximately – 38 feet. The site is now diked to an elevation of approximately + 20 feet. Approximately 1 million cubic yards of maintenance dredged material consisting of predominately silts and clays is dredged from the river and pumped to Eagle Island annually. Much of the interior portion of each cell is covered with a dense growth of *Phragmites australis* and other vegetation.

A cross dike, which has been constructed across the CDF, subdivided the site into two major upland diked disposal areas or cells for management purposes. The south cell covers approximately 300 acres. The north cell covers approximately 650 acres. Each cell is used for two years running. Discharge of dredged material is then cycled to the next cell. The inactive cell is then allowed to dry out by dewatering with dike construction and ditching being performed during the interim period prior to future use.

The Wilmington District is proposing to expand the disposal capacity on Eagle Island by creating a third cell (North Cell Extension) which will be located north of the existing north cell. The proposed north cell extension will be approximately 200 acres in size. The north cell would then be subdivided which would result in the creation of four disposal cells on the island.

**2. Purpose of this Report.** As a result of heavy mosquito population outbreaks during the summer of 1995, a petition asking Brunswick County to abate the mosquito problem was circulated in the town of Leland and subsequently presented at a county commissioners' meeting. Questions were asked and answered at this meeting as to the cause of the outbreaks. In response to this county commissioners' meeting, the U.S. Army Corps of Engineers, Wilmington District, and the state of North Carolina, Public Health Pest Management, Coastal Mosquito Control, asked all agencies directly involved with mosquito control and/or dredged material disposal on Eagle Island (the State of North Carolina, the U.S. Army Corps of Engineers, Wilmington District, New Hanover County and Brunswick County) to meet on November 28, 1995, to identify the problem(s) and to develop management measures to address concerns raised. Participants at this meeting are identified in attachment 1. During this meeting, an interagency work group was formed to identify the nature and extent of this problem and to develop management measures to address the problems identified. Members of the work group are also identified in attachment 1. The purpose of this report is to present to the full committee the findings of this work group. Several background documentation meetings were held. One site visit was made to the island to document conditions in the field and to verify information collected.

**3. Mosquito Ecology on Eagle Island.** Documentation from previous surveillance of the island indicates that pest mosquitoes breeding on the island consist primarily of two salt marsh mosquito species: *Aedes taeniorhynchus* and *Ae. sollicitans* ( Attachments 2 through 4). Both species along with several others have been documented through collection and identification on Eagle Island (Reference 1). The critical breeding season for these species is from mid- March through October, with the critical management and control season being July and September. The life cycle of these floodwater mosquito species requires a dry period when the eggs are "conditioned," followed by a wet flooded period when the eggs hatch into larva. The larva go through several stages and emerge as adults in the floodwater. When the disposal area starts to dry out, as required for dredged material management (see section 2), the mosquito breeding potential of the area increases. When the dredged material and the eggs dry out, the next flooding from rainfall "trigger" the eggs to hatch.

Breeding areas are thus associated with low spots of standing water with cracked clay material, which holds water in each crack. Frequent rainfall often leads to repeated production of mosquitoes as the habitat dries, cracks, and floods. Under optimum conditions, mosquitoes emerge from dredged material disposal sites usually within 5-10 days after a rain. Multiple broods of salt marsh mosquitoes are produced each year after rainfall fills crevices every where in the drained cell. Salt marsh mosquitoes deposit desiccant resistant eggs on the side of crevices in the cracks in the deposited material which can remain viable for years so that a heavy rainfall that floods new areas can produce large a population. Once a brood of mosquitoes is “triggered” by rainfall and the adult stage is reached, female salt marsh mosquitoes disperse into the surrounding areas. After they find a blood meal, they return to the same general area to lay eggs, and the cycle occurs again. All eggs do not hatch every time it floods, so there are always eggs to hatch when another flooding occurs. After each rainfall eggs hatch to produce a brood of mosquito larva. The development from newly hatched larva to adult requires only five or six days in the summer. Females commonly fly up to 10 miles from the breeding sites.

Based on past surveillance, mosquito-breeding areas on the Eagle Island CDF are found both within the interior portion of each cell as well as around the outer rim of the dike. Seepage water from the disposal area through the wall of the dike into surrounding disturbed areas produces mosquito-breeding habitat outside of the cell. Seepage water from inside the dike trapped in low areas between the existing dike wall and an old remnant dike provides ideal mosquito breeding habitat. Access to the outside dike wall for surveillance and control purposes is hampered by heavy vegetation blocking existing natural drainage. Unfortunately, cutting access drains from the river to the outside the dike to remove the water would weaken the structural integrity of the dike itself.

**4. Management Options and Recommendations.** The following measures have been identified as potential solutions to the mosquito breeding problems on Eagle Island:

**a. Mosquito Surveillance Program.** Current surveillance of the CDF to identify and document breeding and treatment areas should be upgraded using larval surveillance. Additional personnel may be needed.

**b. Surface water management.** Expanded use of water management within each disposal cell during and after disposal operations should be considered. Construction of rim ditches and step berms along the inside and outside perimeter of each cell during dike repairs/raising should be pursued.

**c. Biological Control Measures.** More efficient use of biological controls through mosquito fish stocking, maintenance of fish populations, and maintenance of migration routes within each cell should be pursued.

**d. Vegetative control measures.** Controlled burns within the dikes to increase accessibility in heavily vegetated areas should be evaluated. The potential use of chemicals and other control methods should also be considered.

**e. Chemical Control Measures.** Aerially applied larvicides should be considered in conjunction with increased surveillance. Improved targeting of larvicide applications based on continuing long-term surveillance on the island should be pursued.

**5. Mosquito Surveillance Program.** Formal surveillance of mosquito activities on Eagle Island is currently being performed by New Hanover and Brunswick Counties, through a cost reimbursement program with the Wilmington District U.S. Army Corps of Engineers. The current agreement between New Hanover County and the Corps involves both surveillance and chemical applications for control measures. Brunswick County limits their participation to only surveillance on Eagle Island since their

agreement for control and abatement covers other dredged material disposal areas in Brunswick County. An interagency agreement should be developed and coordinated with both counties to ensure surveillance and management controls are similar. Oversight could be provided by the North Carolina Department of Environment, Health, and Natural Resources (NCDEHNR), Vector Control Branch. A model cooperative agreement from the state of South Carolina is included as attachment 5.

Surveillance of Eagle Island for potential mosquito breeding areas should continue to be conducted prior to the start of the mosquito-breeding season. This is normally done during the December-January timeframe. This surveillance should include site location and documentation using GIS positioning, which allows a more accurate location of the breeding areas during the peak breeding seasons. Representative surveillance sites should be monitored during peak breeding seasons. During the mosquito breeding season between March and October, surveillance should be conducted on a weekly basis, with adjustments, as necessary, to meet changing conditions (i. e., monitoring should not be fixed, but should involve intensive surveillance and use of chemical application based on conditions). Additional personnel and increased monitoring may be necessary during the mosquito-breeding season. Surveillance will require close coordination between the counties and the Corps. The frequency of treatment may need to be increased during the breeding season, based on the monitoring. Mowing of dikes and other accessible areas should continue to be implemented to facilitate maximum access for surveillance and mosquito control during the mosquito-breeding season.

**6. Surface Water Construction Measures.** Water management can provide long-term control of mosquito populations on Eagle Island. Current management practices call for the drainage of each cell after completion of disposal operations; however, removal of ponded water in the CDF increases habitat conditions conducive to mosquitoes breeding (see section 3).

**a. Surface Water Management.** Ideally, potential mosquito breeding areas covering large areas within the CDF could be eliminated by keeping a minimum of two feet of water in the CDF during and between disposal operations. Ponded water over large areas within the cell would reduce drying and cracking of the deposited material and would improve conditions for mosquito-eating fish populations in the cell. Maintenance of two feet of water throughout the cells could be achieved by controlling the boards in the discharge spillways after a disposal operation. This option, however, would eliminate drying and reworking of the disposal calls.

**b. Construction measures.** Isolated ponds of brackish water provide habitat conditions for mosquito breeding (Reference 2). Discontinuous ponded areas provide ideal breeding areas with no avenue for the movement of mosquito fish from pond to pond. Most ponded water in the cell results from isolated borrow pits for dike construction and the lack of positive drainage. Positive drainage management would remove ponded water as well as provide an avenue for the movement of mosquito fish to feed on the mosquito larva. The feasibility and effectiveness of constructing a rim ditch on the inside of each cell immediately following disposal or construction activity to allow free movement of brackish water within the cell should be investigated. This ditch would also eliminate borrow pit swale habitat adjacent to the dike wall.

Brackish water seeping from inside the dike may be creating breeding areas along the outside perimeter of the dike. Seepage around the south cell appears to collect in the depressions between the existing dike wall and the former dike cell wall. To help reduce mosquito habitat outside of the dike in these depressions, fill material could be used to level depressions so that they do not collect water. Construction of an outside toe berm around each dike may provide stability to the dike wall as well as remove any low areas which collect seepage water.

Long-term management of Eagle Island CDF could be achieved by preparing a Construction/disposal plan incorporating the above options. A working draft of a construction/dredged material disposal schedule for Eagle Island is included as attachment 6.

**7. Chemical Control Measures.** Ground spraying equipment is the current method of chemical control on Eagle Island. The most common insecticide currently being applied in breeding areas is Bti (*Bacillus thuringiensis* var. *israelensis*), with alternate use of Methoprene. Permethrin products are used for adult control. Chemicals are usually sprayed from the disposal area dikes using truck-mounted equipment. In heavily vegetated areas, Bti is usually applied by hand. Chemical application is limited to areas of around 300 feet from the application equipment. Inaccessible areas within the interior of the cell are usually not sprayed, especially during the summer when poor soil conditions and heavy vegetation hinders access.

Based on past monitoring, we recommend that chemical control measures be applied both aerially and by ground equipment. The effectiveness of aerial spraying by fixed-wing aircraft is limited due to altitude requirements of the aircraft, the speed of the aircraft, and wind conditions. Adulticide application by helicopter would provide more intense and accurate spraying of specific problem areas. A cooperative agreement should be developed to address contracting requirements and responsibilities for aerial spraying.

Vegetation cover critically affects chemical applications within each cell. The need and possible methods to control vegetation in each cell should be investigated. Currently, heavy vegetation obscures mosquito-breeding areas and prevents equipment access. Regular mowing currently provides limited access for equipment.

**8. Biological Control Measures.** Biological control measures primarily involves placing and managing larvivorous (mosquito larva-eating) fish or minnows within each cell. The mosquito fish (*Gambusia affinis*) is very effective for this technique. Control of water in the cell and provision for positive drainage helps to maintain a large population of *Gambusia* sp. Isolated ponded areas tend to be without minnows unless the fish are physically relocated. To provide access, the interior toe dike should be continuous around each cell and have positive drainage to allow the movement of minnows into areas of standing water. Hand stocking of fish can be done for large isolated ponds. Larvicides (see chemical controls above) are also used in breeding areas with active larval populations. Breeding areas are treated with a granular formulation of the larvicide *Bacillus thuringiensis* var. *israelensis* (Bti) dispersed by hand application.

**9. Other Dredge Disposal Areas.** Because mosquito breeding occurs in many areas where dredge disposal is contained, similar to Eagle Island, the state of North Carolina recommends that all dredged material disposal facilities in the Wilmington District be considered potential breeding sites. All problem sites should be surveyed for breeding and corrective measures planned.

# 2000 Wilmington Harbor Interagency Work Group Report

Brunswick County, New Hanover County, State of North Carolina,  
United States Army Corps of Engineers

**1. Eagle Island Confined Disposal Facility (CDF).** The Eagle Island CDF is an upland diked disposal island situated in Brunswick County and bordering New Hanover County. Eagle Island is situated on marsh with an original elevation of approximately + 4 feet, with a foundation of soft deposits extending down to approximately – 38 feet. The site is now diked to an elevation of approximately + 20 feet. Approximately 1 million cubic yards of maintenance dredged material consisting of predominately silts and clays is dredged from the river and pumped to Eagle Island annually. Much of the interior portion of each cell is covered with a dense growth of *Phragmites australis* and other vegetation.

The United States Army Corps of Engineers (USACE) divided the north cell (650 acres) into 2 cells of 325 acres each. A cross dike was constructed between the 2 cells. Eagle Island now consists of three major upland-diked disposal areas of approximately 320+ acres each. Discharge of dredged material is cycled from one cell to the next based on the needs of the USACE.

## **2. Purpose of this Report.**

The creation of a third cell within Eagle Island combined with the increased dredging requirements of the Wilmington Harbor Project suggests the operational strategy for mosquito control on the island needs to be reevaluated for the upcoming 2001 mosquito control activities.

## **3. Mosquito Control Strategies Available in 2001**

**Flooded Cell (Surface water management.)** Expanded use of water management within each disposal cell during and after disposal operations should be continued whenever possible. Ideally, mosquito-breeding areas within the CDF can be eliminated by keeping water in the cell during and between disposal operations. Ponded water over large areas within the cell reduces the surface area for mosquito oviposition and improves conditions for mosquito-eating fish and the production of insect predators in the cell. Maintenance of water levels within the cell can be achieved by managing the boards in the discharge spillways after a disposal operation.

**Transition Cell (Dewatering.)** Periodically, each cell must be drained and dried so the interior of the disposal cell can be reworked to facilitate future disposal operations. The keys to dewatering efforts are the timing of the surface water removal and the creation positive drainage to the weirs. The USACE should continue to provide both a short term and long term schedule of disposal operations to local programs. This is done at each quarterly meeting of the workgroup. The timing of dewatering efforts during the months of June, July and August is critical to mosquito control activities on the Island.

Positive drainage is the goal of dewatering. This is achieved using weir board management and placing a perimeter ditch around the cell. The starting point for the perimeter ditch is usually located on the side of the dike where the weirs are located, at the point where the disposal material is highest. The timing of this operation is critical. The USACE maintenance schedule and the stability of the material within the cell usually dictate the start time for dewatering efforts. Throughout the dewatering process onsite operational decisions are made and digging priorities are adjusted to facilitate positive drainage as the material stabilizes. Lowering the perimeter ditch in a stepwise fashion as weir boards are removed is the key to establishing positive drainage within the cell.

**Dry Cell (Dike Construction)** Control strategies during this phase of cell management usually requires ground based IPM efforts. Spot treatments utilizing biologics, larvicides and adulticides are the tools most often used.

**Projected 2001 Dry Down Schedule (Center Cell)**

Dec-January –Initiate dry down (weir board management) When notified pumping complete.  
March- Start perimeter ditch  
April 30-Complete perimeter ditch  
May, June, July- maintain larval and adult surveillance, have emergency aerial funds available,  
August-start dike construction center cell if possible

**Projected Dry down Schedule (North Cell)** Assuming August Sept 2001-02 Pump date?

August-December pumping  
Dec-January –Initiate dry down (weir board management)  
March- Start perimeter ditch  
April 30-Complete perimeter ditch  
May, June, July- maintain larval and adult surveillance, have emergency aerial funds available,  
August-start dike construction center cell if possible

**Projected Dry down Schedule (South cell)** Assuming August Sept pump date 2003-04 date?

Cell will remain dry due to dike construction  
August-December pumping  
Dec-January –Initiate dry down (weir board management)  
March- Start perimeter ditch  
April 30-Complete perimeter ditch  
May, June, July- maintain larval and adult surveillance, have emergency aerial funds available,  
August-start dike construction center cell if possible.

**4. Other Integrated Pest Management Tools.**

- a. Mosquito Surveillance Program.** Regular surveillance of the CDF should be maintained to identify and document treatment areas and mosquito population trends throughout the upcoming season.
- b. Identification of Critical Treatment Periods.** The critical control periods for each mosquito species of concern should be identified. Critical treatment periods address both individual brood control operations and seasonal species peaks.
- c. Biological Control Measures.** The use of biological controls through mosquito fish stocking, and by taking advantage of natural predatory insect populations should continue.
- d. Vegetative control measures.** Mowing maintenance of dike for equipment access should be maintained.
- e. Chemical Control Measures.**
  - Ground larvicides
  - Aerially applied larvicides will be utilized when other IPM control operations are not feasible
  - Ground ULV applications
  - Emergency inventory should be maintained
- f. Seed Hole management**
  - Cell Full of Water-Seed holes full of water due to seepage from within the dike. Produces Cx. salinarius and An. bradleyi.
  - Cell Dry-Seed holes influenced by rainfall produces Ae. sollicitans and Ae. Taeniorhynchus.

**5. Disease Considerations** West Nile Virus: we may change the species targeted for control because of this new threat Eastern Equine Encephalitis -North Carolina experienced the most active EEE season in the states recorded history in 2000.

<b>Corps District: Charleston</b>	<b>CDFs:</b>	
<b>District Contacts:</b>  Norman Moebs, Operations 843-329-8136 Allen Shiery, Environmental 843-329-8166	AICWW Coastal CDFs	
	<b>Name</b>	<b>Size (acres)</b>
	Clouter Creek	1600
		400/600/25
<b>Contractor Contacts:</b>  Charleston District contracts with two counties: Charleston County Mosquito Abatement for Charleston Harbor and many small AICWW CDFs Martin Hyatt 843-202-7606  Gerogetown County for small CDFs along the AICWW North of Charleston	<b>Ownership</b>	
	1 of 3 cells Corps	
	Navy	
Small AICWW CDFs		
<b>Costs Information:</b>		
Per the contract documents:		
Larvicide: Air 16.34 \$/acre		
Helicopter 16.56 \$/acre		
Adulticide: Air 0.83 \$/acre		
Inspect: Helicopter 680 \$/hr		
(1/10 hr per CDF)		
Amphibius Rotary Ditching 164.52 \$/hr		
<b>Chemicals:</b>		
Altisod, Naled, Malathion		
<b>Procedures:</b>		
The Charleston District operates the sites for Dredged Material Management, not mosquito control. Water management and ditching are for material drying.		
<u>Charleston Harbor – Charleston County Activities</u>		
<ul style="list-style-type: none"> <li>• Inspect after rainfall – dipper counts, sight balls of larvae</li> <li>• Larvacide – Altosid (methoprene liquid on sand) applied by fixed-wing aircraft or a combination of liquid methoprene and B.t.i. by helicopter on small acreages</li> <li>• Ditch as appropriate for dewatering and mosquito control</li> <li>• No biological controls on the dredge management site</li> <li>• Adulticide – Naled (Trumpet) or Malathion applied as liquid from fixed-wing aircraft</li> </ul>		
If failure – the in an 8 mile radius – step up adulticide application from air and truck. 1 to 3 failures each year usually due to weather preventing aircraft application of larvicide.		
<u>No Environmental Assessment</u> – never considered it		
<u>Phragmites Control:</u> No problem		
<b>Attachments:</b>		
Cooperative Agreement with Charleston County (2002, NTE 5 year), pricing schedule Hard Copy only		

<b>Corps District: Savannah</b>	<b>CDFs:</b>		
<b>District Contacts:</b>	AICWW CDFs		
Walt Lanier, Chief of Dredging 916-652-5064	<b>Name</b>	<b>Size (acres)</b>	<b>Ownership</b>
	Chatham County	9 CDFs, 7000 acres	Federal
	Glynn County – Andrews Island	600 acres, small CDFs	Federal
<b>Contractor Contacts:</b>	Mostly small AICWW CDFs		
Agreements with two Counties	<b>Costs Information:</b>		
Chatham County Vector Control Susan Bruce 912-790-2540	No Charge for Chatham County work Glynn County = 100K\$/600 acres		
Glynn County Patrick Taylor 912-554-7720	<b>Chemicals:</b>		
	Aerial Application		
	<u>Chatham applies larvicides:</u>		
	Methoprene-liquid on sand from fixed-wing		
	<u>Glynn applies Adulticide: Naled</u>		
<b>Procedures:</b>			
<u>Chatham County:</u>			
Weekly surveillance Feb-Nov by helicopter to check for larvae			
Rotary Ditching as substrate allows			
Larvicide: Methoprene on blasting sand from helicopters			
Rarely use oils			
No biological controls			
Glynn County :			
Aerial application of Naled by helicopter			
Unspecified larvacide included in rate schedule			
<u>T&amp;E Species</u> – alligators, turtles, piping plover			
<u>No Environmental Assessment</u>			
<u>Phragmites Control:</u>			
Spray liquid Rodeo™ in the Fall after all other plants have gone dormant; follow in the Spring with burning to reduce the mat; then seed with a State-approved wetland mix to reduce emergence			
<b>Attachments:</b>			
Glynn County Contract Agreement for Mosquito Control at Andrews Island Disposal Area			
Hard Copy Only			

## **APPENDIX C**

### **Virginia West Nile Virus Plan 2003**

**Attachment A**

**Attachment C**

# VA WNV Surveillance and Response Plan, 2003

## Mosquito Control Plan

### I. Introduction

The safest, most effective mosquito and arbovirus control programs are based on the practice of Integrated Pest Management (IPM). The basic theory behind IPM is to base control decisions such as target area, time of application, and control method on surveillance findings, and knowledge of the pest, and to apply the best and most appropriate control method(s) or pesticide(s) for each situation. By employing different control methods and pesticides, technicians can deal with various species of mosquitoes during all stages of their life cycle. IPM methodologies also decrease the development of pesticide resistance by minimizing usage of any one type of pesticide/mode of action, and by minimizing frequency and volume of application through appropriate targeting. The way each IPM component is utilized should be tailored to best meet the particular public health needs of each affected locality. The application of pesticides for mosquito control should be a local decision based on local surveillance data and knowledge of local conditions (see Section E. below for recommended response levels). To be effective, control activities must be directed towards the specific target mosquito species (see chapter on mosquito surveillance for further details). Therefore, surveillance will be needed to identify local mosquito populations and the specific biology and habits of the target mosquitoes must be well understood. Information on the biology and behavior of some of the known and suspected WNV vectors is provided in Attachment 4.A.

### General

In Virginia, mosquito control activities are the responsibility of the jurisdiction in which they are required. Section 32.1-187 of the *Code of Virginia* (1950), as amended, provides that counties, cities, and towns may create mosquito control districts. Because of the substantial threat posed by West Nile Virus (WNV) to humans and domestic and wild animals, localities are encouraged to provide additional support to active mosquito control districts, or to establish mosquito control programs in localities where such programs do not currently exist. State and local government agencies should provide citizens with information for managing mosquitoes on their properties. As the first line of defense against mosquito-borne disease, Virginia citizens should eliminate or treat mosquito breeding sites on their own property. Governmental agencies should undertake water management projects on local, state, and/or federal lands where practicable. These projects should include drainage maintenance of ditches and other man made structures that may collect temporary bodies of water, removal of artificial containers that may catch and hold rainwater, larvicidal treatments of habitats that cannot be drained, removed or otherwise changed and the stocking of mosquito eating fish into certain habitats. County or city governments should also enact and enforce ordinances pertaining to accumulations of artificial containers (e.g., VA WNV Plan, 2003 4.2 tire piles, junk, stored materials, etc.) occur on private property, collect water, and serve as a source of local mosquito populations. Adequate control of immature and adult mosquitoes may require the application of insecticides. The decision to initiate insecticide use should be based on an evaluation of its benefit by state and local authorities. When choosing insecticides, preference should be given to effective products or chemicals that are least toxic to humans and the environment. Commercial applicators that apply insecticides for mosquito control must be

certified in Public Health Pest Control (Category-8) in accordance with the *Virginia Administrative Code*, sections: 2VAC20-51-10 through 2VAC20-51-90 (Regulations Governing Pesticide Applicator Certification).

## II. Objective

The objective of the mosquito control plan is to provide mosquito control guidelines for the reduction or prevention of WNV transmission to humans and their domestic animals by mosquito vectors.

## III. Implementation Plan

### A. Non Insecticidal Control

**1. Source Reduction** - The alteration or elimination of mosquito larval habitats is the most effective and economical method of providing longterm mosquito control. Through education and public information releases, state and local governments will provide technical assistance and encourage citizens to participate in source reduction through the removal of used tires, cleaning of rain gutters and bird baths, emptying unused swimming pools, draining or dumping other artificial water containers, unclogging ditches, punching holes in tires used as play ground equipment, and otherwise eliminating potential mosquito breeding sites around the home. State and local government agencies responsible for the maintenance of ditches, streams and stormwater basins on public land should remove tires and other refuse and otherwise maintain these areas in such a manner that they do not become mosquito larval habitats. Standing water in ditches along state roads should be reported to the Virginia Department of Transportation (Tel. 800-367-7623). Problems with mosquitoes breeding in storm water retention ponds should be brought to the attention of the locality's regulatory/maintenance agency such as the local Department of Public Works. **See Attachment D** for guidance from the Department of Conservation and Recreation on design and management of stormwater retention ponds to reduce mosquito habitats. In salt marshes, ditch plugs and other water control structures should be removed or modified to permit daily tidal inundation to occur. The daily tidal exchange eliminates mosquito breeding and eventually restores the area to a productive salt marsh. Open Marsh Water Management, which includes the selective excavation of ponds, pond radials, and ditches, is effective in eliminating mosquito breeding sites and providing permanent habitat for mosquito-eating fish. **NOTE:** Many of these activities in wetlands will require coordination with, and permitting by the district office of the U.S. Army Corps of Engineers and/or the regional office of the Virginia Department of Environmental Quality. Army Corps of Engineers District Offices for Virginia are listed at [www.usace.army.mil/where.html#State](http://www.usace.army.mil/where.html#State); regional DEQ offices are listed at in Appendix 6. Many ditch maintenance activities are exempt from federal and state wetlands regulations, provided that the cross sectional area of the ditch is not modified. However, draining or excavating in wetland areas are regulated activities, and may require federal and/or state permits.

**2. Natural Predators** - Where appropriate, localities may introduce fish, such as mosquito fish (*Gambusia affinis*) into mosquito breeding habitats to control mosquitoes. Habitats where fish may be used to control mosquitoes include storm water retention ponds, stagnant ditches,

backyard ornamental ponds and other man-made or artificial pools of water (residential/municipal). Other fish species, such as fathead minnows, freshwater killifish, certain species of sunfish and even the small fry of game fish (e.g., bass) may also be used to control mosquito larvae and pupae. Care should be taken to avoid stocking mosquito fish into areas that harbor game fish, as many larva-eating fish will also feed on game fish fry. County and city governments, or the mosquito control programs within these jurisdictions must obtain authorization from the Virginia Department of Game and Inland Fisheries (VDGIF) to collect and/or stock mosquito fish (Contact: Becky Wajda [pronounced Vida], Assistant Director, VDGIF Division of Wildlife Diversity; 804-367-8351). Jurisdictions having permits to use mosquito fish can obtain these fish for stocking from a hatchery operated by the York County, VA, Mosquito Control Program (contact James Rindfleisch at 757-890-3790).

**3. Avoidance of Adult Mosquitoes by the Public** - Through public service announcements and other means of outreach, citizens should be advised to install screens on windows and doors of homes and commercial buildings. They should also be advised to protect themselves by: avoiding outdoor areas during times when mosquito populations are actively feeding; wearing hats, socks, and loose fitting, light colored clothing with long pant legs and long sleeves when outdoors; and using mosquito repellents containing DEET, and following safe repellent use practices (Attachment 4.B).

## **B. The Use of Insecticides – General**

**1. Notification:** If it becomes necessary to use insecticide fogs/aerosols for area control of adult mosquitoes, local governments should provide residents with accurate and precise advance information on when and where these pesticides will be applied so that citizens who wish to avoid exposure may take cover and/or take action to protect pets and domestic animals including managed honeybee colonies, and aquaculture projects. Among various methods of informing the public, such as the media, one of the easiest ways to provide this advance notice is to establish a telephone hotline, publicize its number and record daily updates. Broad scale, aerosol/fog insecticide applications that cover areas that have not been surveyed or determined to have active mosquitoes, are not in keeping with prudent IPM practices. Targeted, focused and limited aerosol/fog application should be based on sound, scientific surveillance indicators.

**2. Safe Use of Insecticides:** A list of insecticide active ingredients registered for both larval and adult mosquito control in Virginia is provided in Attachment 4.C. The use of insecticides for mosquito control may be accompanied by risks to non-target organisms including humans. Direct toxicity is the primary concern, and may be reflected in fish or wildlife kills or in episodes of non-lethal effects that render exposed non-target organisms susceptible to other sources of morbidity or mortality. Pesticide application personnel, in particular, are at risk from direct toxic effects of insecticides, and proper precautions must always be taken when handling, mixing and applying pesticides. Equipment used for applying pesticides must be properly calibrated to dispense the pesticide according to label specifications. Whenever any pesticide is applied, the law requires that the directions outlined on the pesticide label be carefully followed. When choosing insecticides for mosquito control, governmental agencies and their contractors should give preference to those products that pose the least risk to humans and the environment. Environmentally friendly insecticides are generally the most effective in the long run because

they help preserve many of the natural enemies that help regulate the size of mosquito populations. The relative risks (toxicity) associated with the currently registered mosquito control insecticides, both larvicides and adulticides are discussed in Attachment 4.C.

**NOTE:** Any fish kills must be reported immediately upon discovery. During business hours contact the closest regional Department of Environmental Quality office; otherwise contact the Department of Emergency Management at 1-800-468-8892.

### C. Use of Insecticides for Larval Control

**1. Larval mosquito control** targets immature mosquitoes in their aquatic habitat before they become flying, biting adults. In general, larval control is the most effective method of controlling some mosquito populations, has the least effect on non-target species, and is applied to the smallest area of the environment. For example, one can treat an acre of aquatic habitat to control mosquito larvae, but if one waits until the adults have emerged and dispersed, one may need to treat 500 acres to kill the adults that emerged from that acre of habitat. Localities may conduct their own larviciding activities, or contract with commercial pesticide applicators to conduct larviciding operations. Larvicides may be applied by hand, or with powered backpack mounted, vehicle mounted or aircraft mounted equipment. Aircraft application of larvicides is most practical when large areas of inaccessible terrain need to be treated quickly. The larvicides that can be used for mosquito control in Virginia include the following:

a. Bacterial larvicides such as *Bacillus thuringiensis* var. *israelensis* (a toxin from a killed bacteria), and *Bacillus sphaericus* (a live bacterial spore) can be used successfully in a broad range of freshwater habitats, but are somewhat unpredictable in salt marsh habitats. *Bacillus thuringiensis* (**Bt**) based larvicides are sold in a variety of formulations (liquid, granule or briquet) under a wide variety of trade names such as: Mosquito Dunks, VectoBac, Aquabac, Bti Briquets. **Bt** based larvicides are quite effective against members of most mosquito genera, but may be slightly less

effective on members of the *Culex* genus. *Bacillus sphaericus* (**Bs**) based larvicides are sold under the trade name VectoLex. **Bs** is highly effective against species in the *Culex* genus, but are not effective against Asian tiger mosquitoes and several other species of *Aedes* mosquitoes. **Bs** works very well in polluted water, where it may be self-perpetuating. Bacterial larvicides are most effective when used against mosquitoes in the 1<sup>st</sup> through 3<sup>rd</sup> larval growth stages, but will not control late 4<sup>th</sup> stage or pupal stage mosquitoes.

b. Biochemical larvicides contain an insect growth regulator called methoprene and are sold under the trade name Altosid. Methoprene is an insect hormone mimic that prevents immature mosquitoes from developing into adults. Altosid products are labeled for use in a wide variety of natural and artificial aquatic habitats and are effective for use in salt marshes. Altosid is relatively target specific and will not harm many aquatic species such as amphibians or aquatic insects having incomplete metamorphosis (e.g., water bugs, damselflies, dragonflies). However, it may be slightly to moderately toxic to some fish species and is toxic to crustaceans such as shrimp or crab species

or aquatic insects with complete metamorphosis (e.g., flies, beetles). Altosid may be somewhat toxic to birds which consume granules that land on dry ground. Altosid is most effective when used against mosquitoes in the 1<sup>st</sup> through early 4<sup>th</sup> larval growth stages, but is not effective against late 4<sup>th</sup> larval stage or pupal stage mosquitoes.

c. Monomolecular surface film larvicide (trade name - Agnique) is sprayed on water to prevent immature mosquitoes from attaching their siphon tubes to the water surface to breathe.

Monomolecular surface films (MSFs) are often used when surveillance indicates that a large proportion of the immature mosquito population has reached the pupal stage which cannot be effectively controlled with microbial or biochemical larvicides. MSFs can be highly effective in puddles, ditches, and other artificial and natural habitats, and in polluted water. MSFs work best on small, sheltered bodies of water, but may be rendered ineffective (blown off the surface) in habitats exposed to excessive wind. Their effectiveness is also reduced in areas of heavy aquatic vegetation. MSFs are inert and will not pollute aquatic environments or harm aquatic organisms such as fish, amphibians, or crustaceans. However, MSFs can harm populations of small aquatic arthropods (e.g., spiders, water striders, etc.) that rely on water surface tension for locomotion or respiration.

d. Surface Oils (Mineral Oils) (sold under trade names such as BVA Oils or Golden Bear Oil) are sprayed as a layer on top of water to suffocate and drown larval and pupal mosquitoes. Surface oils are less affected by wind than monomolecular surface films and are effective in habitats with heavy emergent vegetation. Oils are mostly used when immature mosquito larvae have developed to a stage beyond which other larvicides will control them. Unlike monomolecular surface films, oils are not inert and so they may affect some non-target aquatic organisms. Use of oils on water in environmentally sensitive areas should be avoided. Where possible, the use of oils should be limited to artificial containers, puddles, ditches, and other un-natural habitats.

e. Chemical Larvicides: An organophosphate insecticide called Temephos is the only chemical insecticide sold for control of mosquito larvae. Temephos is sold under the trade name Abate. Abate can be effective in the treatment of puddles, artificial containers (tire piles), and polluted waters high in organic content. Abate is very effective for controlling mosquito larvae, but might also impact fish, amphibians, aquatic arthropods and other aquatic organisms. Therefore, its use should be avoided in environmentally sensitive areas and limited to artificial containers, puddles and other un-natural habitats. Misuse of chemical insecticides such as Abate in semipermanent, artificial and natural habitats (e.g., storm water settlement ponds, semi permanent ponds and wetlands) may impact important predators and natural enemies in the habitat. Elimination of the natural enemies that helped keep the initial mosquito population in check, facilitates a resurgence and recolonization of that habitat by mosquitoes and can lead to a dependence on the continued use of larvicides in that habitat.

## **D. Use of Insecticides for Adult Mosquito Control**

**1. Techniques of Adult Mosquito Control** - Adult control consists of two different methodologies. One methodology is known as “the application of “Ultra Low Volume (ULV) aerosols” and/or “fogging”. The other methodology is known as the application of “barrier treatments”.

**2. Aerosol or Fog Applications for Adult Mosquito Control** – Aerosols/fogs applications are the most widely used method of adult mosquito control and involve a volumetric treatment of air by the dispersal of very fine aerosolized droplets that are light enough to float on the air and be carried over a large area. These small droplets (generally ranging from 1 to 40 microns in size) float on air currents and intoxicate the flying mosquitoes that are impacted by them.

Fogs/aerosols are dispensed in very low doses (ounces per acre) and do not leave any significant residual pesticide layers on surfaces within treated areas. Aerosols and fogs generally only kill

mosquitoes that are in flight because mosquitoes that are resting in sheltered areas are not impacted by sufficient numbers of droplets to get a toxic insecticide dose.

a. Ultra Low Volume (ULV) fogs and aerosols are generated with dispensing machines that physically split a liquid insecticide into very small droplets of a relatively uniform size (narrow size range). Most ULV machines can be set to produce droplets of a particular size within the 1 to 50 micron size range. The production of ULV aerosols/fogs does not require that the liquid insecticide concentrate be mixed with a carrier liquid such as oil or water, so a very small volume (ultra low volume) of liquid insecticide can be converted into a fog/aerosol of relatively pure

insecticide and be dispensed over a wide area.

b. Thermal fogs are generated with thermal fogging machines that heat the liquid insecticide during the process of breaking it into small droplets. Thermal fog droplet sizes may range from 1 to 50 microns, with a large portion of the droplets being in the 10 to 15 micron (visible) size range. Droplets within this size range scatter light and therefore appear as a white cloud.

Insecticides dispensed by thermal foggers must be mixed with a carrier liquid such as oil, so thermal fog applications require more liquid volume per the quantity of insecticide dispensed.

c. Fogs and aerosols are essentially the same thing, but vary slightly in definition. A fog is a visible aerosol because it consists of a large portion of small droplets in the 10 to 15 micron, visible size range. An aerosol is a general term that describes air borne droplets in a variety of sizes from visible, fog-sized, droplets to larger, less visible droplet sizes in the 15 to 40 micron size range. A fog is an aerosol, but an aerosol is not necessarily a fog. The difference between these two terms is technical and for practical purposes, most personnel involved in mosquito control refer to aerosols generated by both ULV machines and thermal foggers as fogs, and refer to both types of machines as foggers. Aerosol droplets in the 40 to 100 micron size range do not float in the air for very long, and can leave a wet residual layer on any solid surfaces they encounter. These larger sized droplets are considered to be a mist.

d. Application of mosquito adulticide aerosols/fogs should be considered and evaluated on a case-by-case basis. Mosquito control response levels (see Section E., Level I-b through V, below) based on local levels of vector mosquito activity and arboviral activity may aid in determining when to apply adulticides. However, this judgment can only be made based on local surveillance data and knowledge of local conditions (e.g., human population density, detected levels of arboviral activity, target mosquito species, mosquito population density, layout of local roads or other geographical features, weather forecast, prevailing wind directions, etc.).

Mosquito aerosol and fog applications should be made using properly maintained and calibrated ULV machines and foggers. Adulticide aerosol/fog applications may be made by equipment that is hand held, or mounted on backpacks, all terrain vehicles, trucks, or on fixedwing or rotary-wing aircraft.

e. Aerial applications of mosquito control insecticides are useful for rapidly treating large areas that cannot be easily accessed or covered in a timely manner by ground based spraying equipment. Due to the speed of coverage, the large area that can be treated, and the uniformity of the coverage, aerial applications are more effective in controlling mosquitoes than ground-based applications. Aerial applications may be recommended when there is a widespread and imminent threat from mosquitoes infected with WNV (see Section E., Response Level V, below).

Depending on the configuration and size of the area to be sprayed, one may need to consider the advantages and drawbacks of using either fixedwing or rotary-wing aircraft for dispersing

insecticides. Aerial applications of pesticides require much advanced planning to identify the areas that should be treated, identify the areas to be avoided, and to properly notify or warn populations and businesses (e.g. beekeepers, aquaculture farmers, food preparation facilities) within the proposed spray area. Properly certified applicators must be aboard each aircraft that is conducting aerial pesticide applications. State and local public health and other governmental agencies may establish pre-existing requirement contracts with commercial pesticide applicators that can be activated on a moments notice when wide-area mosquito control becomes necessary. When the potential for arthropod-vector disease transmission is so high that mosquito control requirements exceed the capability of local and state resources to respond in a timely manner, the state may request assistance from the Federal Emergency Management Agency for emergency funding for contracting aerial mosquito control operations and/or may request assistance from the Department of Defense for aerial application of mosquito control pesticides by the U.S. Air Force.

f. Timing and conditions for adulticide aerosol/fog applications must be appropriate for treatments to be effective. Depending upon the target species, the greatest efficacy will be achieved when applications are made during periods when the target species is in flight. For example, *Culex pipiens*, a primary vector of WNV, is a nighttime biter, and applications should be made starting at dusk and continuing into the nighttime hours. The fogging of daytime flying mosquitoes can be problematic. Fog applications made during daylight hours are often ineffective because warm convective air currents rising from close to ground level will carry the fine aerosol/fog droplets up into the sky. Daylight fog applications can be effective only when there are no convective currents and this may occur during early morning hours, on overcast days, or in heavily shaded areas. Fogging applications should be made when air temperatures are above 50° F because mosquitoes will not fly at lower temperatures. It is preferable to make fogging applications when wind speeds are from 3 to 5 mph. To avoid poor pesticide coverage due to excessive pesticide drift and dilution, fog applications should not be made when wind speeds exceed 10 mph. Applications should not be made from either ground vehicles or aircraft during periods of dead calm because the fog/aerosol will not be carried from the road or aerial spray swath into target areas.

**3. Barrier Treatments for Adult Mosquito Control** – Barrier treatments involve the application (spraying) of residual liquid pesticides on surface areas. A residual pesticide barrier applied to a surface can kill adult mosquitoes that subsequently land on the treated surfaces. Depending on the surface treated, and the occurrence of rain or other factors that might degrade a residual insecticide layer after treatment, residual barrier treatments may be effective for several days to several weeks after application. Barrier treatments are applied to foliage, vegetation, the eaves, ceilings and walls of houses, or any other place where adult mosquitoes are known to land and rest. Barrier treatments may be applied using a simple liquid insecticide sprayer with a fan nozzle, or may be applied using a ULV machine or thermal fogger set to dispense mist-sized droplets in the 40 to 100 micron size range. Portable ULV machines are best used to apply barrier treatments to plants and foliage because relatively small quantities of insecticide can be used to apply a uniform layer of insecticide on a large area of foliage.

**4. Insecticides Used for Adult Mosquito Control** – The products currently registered in Virginia for adult mosquito control include insecticides in the organophosphate, and synthetic pyrethroid classes as well as pyrethrins. Some of the commonly used insecticides currently registered for use as mosquito adulticides in Virginia are listed in Attachment 4.C. Each of these insecticides has advantages and drawbacks as well as label specifications that will influence

which material is most appropriate for a given situation (Attachment 4.C). Considerations should always be made on the adverse impact to non-target species and potential for detrimental health effects on sectors of the human population. Localities seeking additional guidance on appropriate mosquito control pesticides should contact: the Virginia Cooperative Extension at Virginia Polytechnic Institute and State University, Blacksburg, Virginia, Tel. (540) 231-6543; Dr David Gaines, Public Health Entomologist for the VDH-Office of Epidemiology, Tel. (804) 786-6261; or Dr. Marvin Lawson, VDACS Office of Pesticide Services, Tel. (804) 786-3534.

## **E. Recommended Response Levels for Mosquito Control Operations**

**1. Level Ia** – Winter weather, low likelihood of WNV epizootic activity, and little or no adult mosquito vector activity present. Plan and organize mosquito control program elements for larval and adult control. Identify habitats where larval control measures can be applied. Scout and identify locations where drainage/source reduction activities could be applied and identify areas that might require larvicidal control methods once the mosquito season commences. If resources are available,

**2. Level Ib** – Mosquito breeding season, adult mosquito activity present, no current evidence of WNV epizootic activity. Where appropriate and resources permit, conduct ditching, drain cleaning, filling of ruts, and other habitat modification activities for source reduction. Conduct larval control of vector species in identified breeding habitats where source reduction (habitat modification) is not possible. Consider adult mosquito control where large primary vector populations are detected. Implement an education/media campaign to encourage citizens to eliminate container breeding habitats around their homes.

**3. Level II** - Mosquito larvae and adults present, initial evidence of WNV epizootic activity (limited to birds and/or mosquitoes). Where resources permit, conduct programs for larval control in key problem mosquito habitats, continue and enhance source reduction and public education programs. Target larval vector populations and consider use of adult vector control tactics in areas where WNV activity has been detected, and adult vector species have escaped larval control.

**4. Level III** – Moderate WNV epizootic activity in mosquitoes and birds with initial evidence of WNV in a horse or human. Continue, source reduction and public education programs and enhance larvicide programs to target vector breeding habitats in areas of increased WNV epizootic activity. Consider use of adult control tactics in areas where vector species have escaped larval control and where evidence of WNV has occurred. Plan an emergency mosquito control program to be ready if conditions ever reach a state where such operations are needed.

**5. Level IV** – Heavy WNV epizootic activity suggesting high risk of human infection (i.e., high dead and/or positive bird densities, high mosquito infection rates). Confirmed human or horse case, abundant adult bridge vectors. Conduct larval mosquito control and strongly consider use of adult mosquito control tactics targeted at vector populations. Increase control efforts in areas of potential human risk.

**6. Level V** – Multiple human cases of WNV and conditions favoring further transmission to humans.

Implement emergency larval control and strongly consider use of adult mosquito control tactics. If outbreak is widespread, covers multiple jurisdictions, and mosquito populations originate from large habitats inaccessible to ground vehicles, consider conducting aerial application of larvicides and adulticides targeted to known and potential areas of vector mosquito activity.

## Known and Suspected Mosquito Vectors of West Nile Virus

### *Culex pipiens*

Among the more common mosquito pests in Virginia, *Culex pipiens* is found in urban and suburban communities as well as on rural premises. It breeds in underground storm sewer catch basins; artificial containers; gutters; polluted ground pools; bird baths; discarded tires; animal waste lagoons; farm animal wallows; clogged, grass choked ditches; in effluent from sewage treatment plants; and in other sites that are slightly to very eutrophic or polluted with organic wastes. This mosquito is a nighttime flyer that will invade houses where it will hide in corners and in dark places during the day. This mosquito feeds principally on birds, but will feed on humans, particularly when inside a house. *Culex pipiens* over-winters as adult mosquitoes, hiding in culverts, under houses, and inside outbuildings. In the spring, eggs are laid on top of water, in suitable habitats. The eggs hatch into larvae that mature rapidly when water temperature and nutrient levels are relatively high. *Culex pipiens* females may travel up to 3/4 of a mile in a single night in search of a blood meal, but generally are found within 1/2 mile of their breeding habitat. *Culex pipiens* is the most important primary vector for WNV (amplifies WNV in the bird population). *Cx. pipiens* were the most common field collected mosquito to be found carrying WNV in during 1999, 2000 and 2001. For example, in 2001 there were five times as many *Cx. pipiens* that tested positive for WNV as *Cx. restuans*; *Cx. restuans* were the second most common field collected mosquito to test positive for WNV. *Cx. pipiens* are generally not readily trapped in large numbers with CDC traps, so low numbers in a CDC trap do not necessarily indicate low numbers in the environment. Their populations are best monitored with gravid traps baited with an appropriate infusion bait.

### *Culex restuans*

Among the more common mosquitoes in Virginia, *Culex restuans* is found in most of the same breeding habitats as *Cx. pipiens*. *Cx. restuans* becomes active in the early spring and is the most common *Culex* species found during the springtime. *Cx. restuans* becomes less common during the warm summer months when *Cx. pipiens* is most active. *Cx. restuans* is a night biter that feeds exclusively on birds. Laboratory trials show them to be moderately competent WNV vectors, but they are probably the second most important primary vectors that amplify WNV in the bird population and they were the second most common field collected mosquito species to test positive for WNV during the 1999, 2000 and 2001 seasons. *Cx. restuans* are more readily trapped with properly baited gravid traps than CDC traps. Low numbers in a CDC trap do not necessarily indicate low numbers in the environment.

### *Culex salinarius*

This species was identified as the most likely bridge vector for human WNV cases on Staten Island, NY in 2000. It is the third most common mosquito species to test positive for WNV. *Cx. salinarius* breeds in temporary flood-pools on the margins of freshwater, brackish or saltwater marshes. It may also be found breeding in any grass choked, stagnant puddle, or in large artificial containers containing a mixture of water and grassy organic matter or other vegetation. It can be found anywhere in Virginia and can be among the most abundant species in

some areas during the summer. It is attracted to CO<sub>2</sub> baited CDC traps and is often caught in large numbers in coastal communities. *Cx. salinarius* is a nighttime flyer that may invade houses. It feeds readily on both birds and large mammals including humans. The flight range of *Cx. salinarius* is approximately 2-3 miles. It overwinters as an adult in rodent burrows, culverts or other sheltered areas, and may become active even during the winter months on nights when the air temperature is high enough to allow flight (e.g., >50°F).

#### ***Ochlerotatus triseriatus***

This mosquito known as the “eastern tree hole mosquito” is found throughout Virginia. *Oc. triseriatus* favors laying eggs in tree holes (holes in stumps or tree trunks that hold water), but also breeds in artificial containers that are in shady locations and are polluted with some tree debris (leaves, etc.). It is often found in association with tire piles. *Oc. triseriatus* feeds during the day and its flight activity generally ends at dusk. *Oc. triseriatus* typically does not travel more than about 500 ft from its breeding habitat, so if tree hole mosquitoes are an identified problem, their breeding habitat is generally going to be close by. *Oc. triseriatus* has been identified as a moderately efficient WNV vector in the laboratory, but field data in 2000 and 2001 have shown it to be the fifth most common mosquito species found carrying WNV. *Oc. triseriatus* is the most important vector of LaCrosse Encephalitis. *Oc. triseriatus* are not readily trapped with CDC traps, so detection of low numbers with a CDC trap may mean that there are many more in the environment.

#### ***Ochlerotatus japonicus***

This mosquito was first discovered in the United States in New York in 1998. Since that time it has been discovered throughout the states of Connecticut, New Jersey, and Pennsylvania. More recently it was discovered in central and western Maryland, Washington D.C., and northern Virginia and has been found in counties along the Shenandoah Valley and Blue Ridge mountains as far southwest as Roanoke Virginia. *Oc. japonicus* is associated with rock pools (holes in rock outcrops that hold water), but it breeds equally well in all forms of artificial containers. It can be found sharing its breeding habitat with *Oc. triseriatus* and like that species, becomes active relatively early in the season. Little is known about *Oc. japonicus*’ flight range, or its feeding preferences, but it will bite humans. It was the sixth most common field collected mosquito to be found carrying WNV in 2001. In laboratory trials it has been shown to be a highly efficient vector of WNV. *Oc. japonicus* are not readily trapped with CDC traps, so detection of low numbers with a CDC trap may mean that there are many more in the environment..

#### ***Aedes albopictus***

This mosquito is a container breeder that is found throughout Virginia and is easily the most common urban, suburban and rural nuisance mosquito associated with artificial breeding habitats. *Ae. albopictus* feeds during the day and its flight activity generally ends at dusk. However, it will enter homes at dusk, and once inside, will bite during the night even in darkness. *Ae. albopictus* does not become active until mid spring (mid May) and is most common during the summer months. This mosquito favors laying eggs in artificial containers that are in shady locations and are polluted with some tree debris (leaves, etc.), but it will also

breed in tree holes and rock pools. It is often found sharing larval habitats with *Oc. triseriatus* and *Oc. japonicus*. *Ae. albopictus* does not frequently travel more than about 500 ft from its breeding habitat, so if tiger mosquitoes are an identified problem, their breeding habitat is going to be close by. Populations of this mosquito are usually greatest around bushes and foliage nearest to the breeding habitat. *Ae. albopictus* has been identified as one of the most efficient WNV vectors in the laboratory, but its role in field transmission is still unclear. *Ae. albopictus* may also be an important vector of LaCrosse Encephalitis. *Ae. albopictus* are not readily trapped with CDC traps, so detection of low numbers with a CDC trap may indicate that there are many more in the environment.

#### ***Ochlerotatus atropalpus*,**

This mosquito, known as the “rock pool mosquito” breed mostly in rock pools (holes in rock outcrops that hold water), but have been known to occasionally breed in artificial containers, away from the rocky stream or river habitats where they are usually found. Like most other container breeding mosquito species, this mosquito feeds during daylight hours and does not venture far from its breeding habitat. They are known to bite humans and can be persistent biters near their habitat. Laboratory trials have shown *Oc. atropalpus* to have one of the highest WNV vector competencies, but due to their limited distribution (mostly in places where rock pools occur) few have been captured and tested, and none have been found carrying WNV.

#### ***Aedes vexans***

This mosquito is a floodwater breeder found throughout Virginia. It breeds in a great variety of temporary flood-pools, usually in woodlands or grassy sites (fields, ditches), and can be produced in large numbers in these habitats. Eggs are laid in moist depressions, especially those containing moist organic debris, and hatch when they are flooded by water. Eggs may hatch during the same season in which they were laid, or may also sit for several seasons until stimulated to hatch by floodwater. Several generations of this mosquito can occur each year. *Ae. vexans* has a flight range of 5 to 10 miles and feeds during dusk and after dark. Laboratory studies have shown it to be relatively inefficient as a WNV vector, but this mosquito can occur in large numbers and was suspected of being an important WNV bridge vector to horses and humans in New Jersey in 2000.

#### ***Ochlerotatus sollicitans***

This mosquito is a saltmarsh breeder found primarily in coastal Virginia, but may occur anywhere in the state where water habitats and salinity levels are adequate. It is a fierce aggressive biter that can be produced in large numbers in saltmarsh habitats. *Oc. sollicitans* has a flight range of 5 to 10 miles, but may travel 40 or more miles. It takes feeding flights during dusk and after dark and is strongly attracted to lights, so it may migrate from salt marshes toward nearby towns. However, it will feed at any time during the day when its resting sites are invaded. Laboratory studies have shown it to be a moderately efficient WNV vector, but field studies have also shown that this mosquito feeds mainly on large animals and only a small proportion of its blood meals come from birds. Thus, only a low proportion might be infected with WNV. However, this mosquito can occur in huge numbers and care should be taken to avoid excessive exposure to them.

### Other Mosquito Species

As the transmission of WNV is new in the United States, our knowledge of its vectors here is incomplete. During the 2001 season, 24 species of mosquitoes were found in the field carrying West Nile virus; 22 of those species are found in Virginia (see Table 1 below). About a dozen species of mosquitoes have been tested in the laboratory for their WNV vector competence (ability to become infected with, and transmit WNV). Those species that occur in Virginia and have high or moderate WNV vector competence have been described above. Other tested species have shown only low vector competence or no ability at all to become infected with and transmit WNV. Several other mosquito species in the *Ochlerotatus* genus have demonstrated potential to be WNV vectors in the laboratory and/or field. These include floodwater and salt marsh species. Thus far, the only floodwater species besides *Ae. vexans* to show potential as WNV vectors are *Oc. canadensis*, and *Oc. trivittatus*; a number of each of these mosquito species collected from the field in over the past three years in Northeastern United States, were carrying WNV. Other mosquito species that may serve as WNV vectors are likely to be discovered. Based on further surveillance information from other states and from Virginia's mosquito surveillance program, other species will be added to the known and suspected list as their vector potential is discovered.

**Table 1: Field collected mosquito species found to be carrying West Nile virus (WNV) in the United States in 2001 and 2002 (carrying WNV does not necessarily mean that the mosquito was infected with, or had the ability to transmit the virus while feeding).**

Rank	Total Positive Pools Found	Species	WNV Vector Competence	Vector Status *
1	1,286	<i>Culex pipiens</i>	Moderate	Primary & Bridge vector
2	346	<i>Culex restuans</i>	Moderate	Primary vector
3	141	<i>Culex salinarius</i>	High	Bridge & Primary vector
4	73	<i>Ochlerotatus triseriatus</i>	Moderate	Bridge vector
5	57	<i>Aedes vexans</i>	Low	Bridge vector
6	48	<i>Aedes albopictus</i>	High	Bridge vector
7	36	<i>Anopheles punctipennis</i>	Unknown	Bridge vector ?
8	35	<i>Ochlerotatus jap. japonicus</i>	High	Bridge vector
9	22	<i>Culiseta melanura</i>	Unknown	Primary vector ??
10	22	<i>Anopheles quadrimaculatus</i>	Unknown	Bridge vector ?
11	19	<i>Culex erraticus</i>	Unknown	Bridge vector
12	15	<i>Coquillettidia perturbans</i>	Low	Bridge vector
13	14	<i>Ochlerotatus trivittatus</i>	Unknown	Bridge vector ?
14	8	<i>Ochlerotatus sollicitans</i>	Moderate	Bridge vector
15	6	<i>Ochlerotatus taeniorhynchus</i>	Low	Bridge vector
16	6	<i>Ochlerotatus can. canadensis</i>	Unknown	Bridge vector ?
17	6	<i>Psorophora columbiae</i>	Unknown	Bridge vector ?
18	4	<i>Anopheles barberi</i>	Unknown	Bridge vector ?
19	2	<i>Aedes aegypti</i>	Moderate	Bridge vector
20	2	<i>Orthopodomyia signifera</i>	Unknown	Unknown ?
21	1	<i>Aedes cinereus</i>	Unknown	Bridge vector ?
22	1	<i>Anopheles walkeri</i>	Unknown	Bridge vector ?
23	1	<i>Culex territans</i>	Unknown	Unknown ?
24	1	<i>Culiseta inornata</i>	Unknown	Unknown ?
25	1	<i>Ochlerotatus atlanticus</i>	Unknown	Bridge vector ?
26	1	<i>Ochlerotatus cantator</i>	Unknown	Bridge vector ?
22	1	<i>Psorophora ciliata</i>	Unknown	Bridge vector ?
24	1	<i>Uranotaenia sapphirina</i>	Unknown	Unknown ?

\* Primary vectors feed on birds and maintain WNV in bird population; Bridge vectors feed on numerous animal species including horses, humans and birds and serve as a bridge for the virus to move from bird to mammal.

## Pesticides Registered in Virginia Commonly Used to Control Mosquitoes

**Larvicides:** Insecticides applied to bodies of water identified as mosquito breeding areas to kill mosquitoes during the larval or pupal stages.

- ***Bacillus thuringiensis israelensis (Bti)*.** Spores of this naturally occurring soil bacterium contain a pure toxin which disrupts the gut of mosquitoes and primitive fly species by binding to receptor cells present. It has little effect in other insect species. Bti will not affect mosquito larvae that have developed past the late 4<sup>th</sup> instar, or are in the pupal stage of development. Bti is not toxic to birds, mammals or fish and is practically non toxic to amphibians.

*Bacillus thuringiensis israelensis* (Vectobac formulation\*) has an oral LD<sub>50</sub>\* (rats) of >5000 mg/kg, and a dermal LD<sub>50</sub>\* (rabbits) of >2500 mg/kg.

- ***Bacillus sphaericus*.** A naturally occurring bacterium also contains a toxin that disrupts the gut of mosquito larvae by binding to receptor cells found in certain species of mosquitoes. *B. sphaericus* will not affect mosquito larvae that have developed past the late 4<sup>th</sup> instar, or are in the pupal stage of development. *B. sphaericus* is not toxic to mammals or other animal groups. Data on toxicity to other arthropods is unavailable.
- ***B. sphaericus*** is very effective against *Culex* mosquito species found in water with high organic content.

*Bacillus sphaericus* (Vectolex formulation\*) has an oral LD<sub>50</sub>\* (rats) of >5000 mg/kg, and a dermal LD<sub>50</sub>\* (rabbits) of >2000 mg/kg.

- **Methoprene.** (Altosid). An insect growth regulator that prevents the normal maturation of insect larvae. Methoprene will not affect mosquito larvae that are developed past the late 4<sup>th</sup> instar, or are in the pupal stage of development. Methoprene has little effect on mammals, snails, frogs, mosquito fish, or on aquatic insects from orders with incomplete metamorphosis (e.g., will not affect mayflies, stoneflies, dragonflies, or damselflies, but may affect aquatic beetles and true flies). Methoprene may be slightly toxic to birds and slightly to moderately toxic to some species of fish. It may be highly toxic to aquatic to freshwater and estuarine invertebrates such as crabs or shrimp.

Methoprene (technical grade) has an oral LD<sub>50</sub>\* (rats) of >5000 mg/kg, and a dermal LD<sub>50</sub>\* (rabbits) of >2000 mg/kg.

- **Temephos.** (Abate). An organophosphate insecticide that has a low to moderate mammalian toxicity. Temephos is highly effective against all mosquito larval stages but will not easily kill mosquito pupae. Temephos

can be highly toxic to some bird species and to some aquatic organisms such as certain fish species, freshwater insects, and other invertebrates (e.g., shrimp, crabs, mollusks).

Temephos (technical grade) has a variable oral LD<sub>50</sub>\* in rats that could be as low as 1226 mg/kg, and a dermal LD<sub>50</sub>\* (rabbits) of 1155 mg/kg.

- **Monomolecular Films** (Agnique). Chemicals which spread a thin film on the surface of the water and make it difficult for mosquito larvae, pupae or emerging adults to break through or attach to the water's surface, causing them to drown. Typically films remain active for 10-14 days on standing water.
- **Surface Oils**. Similar to monomolecular films, oils form a coating on top of water to drown larvae, pupae and emerging adult mosquitoes. Oils do not pose a risk to human health. However, they may be toxic to amphibians, fish and other aquatic organisms if misapplied.

**Adulticides:** Insecticides, typically applied with ultra low volume (ULV) spray equipment, that dispenses the pesticide as a fine fog to kill adult mosquitoes. ULV releases a few ounces per acre of treated area, and is released as tiny particles (generally <50 micron sized droplets) of insecticide solution that drift in the air. Insecticides can only be used for fogging applications if they are labeled for that purpose. Adulticides may also be applied as a liquid surface spray or applied as a ULV mist (larger droplet sizes of >50 microns) to leave a toxic residual "barrier treatment" on surfaces (walls, ceilings, eaves and shrub or ivy foliage) where mosquitoes land and rest. Insecticides can only be used for barrier treatments if they are labeled for that purpose.

**Organophosphate Insecticides** – Because organophosphates are neurotoxins that readily affect mammalian nervous systems (cholinesterase inhibitors), exposure to high doses can over-stimulate the nervous system and cause convulsions, respiratory paralysis and death. Most organophosphates are toxic to fish and aquatic invertebrates and are highly toxic to honeybees.

- **Malathion**. An organophosphate insecticide applied by truck-mounted or aircraft-mounted ULV sprayers at a maximum rate of 0.23 pounds (2.5 fluid ounces) of active ingredient per acre. Malathion has a relatively low toxicity to humans and other mammals, is moderately toxic to birds and has a wide range of toxicities to different fish species. It is highly toxic to amphibians and aquatic invertebrates, and should not be applied over water with ground fogging equipment. Malathion is highly toxic to honeybees and should not be applied at times and locations where bees are foraging.

Malathion (e.g., Fyfanon ULV formulation) has an oral LD<sub>50</sub>\* (rats) of 2830 mg/kg; a dermal LD<sub>50</sub>\* (rats) of 2000 mg/kg; and an inhalation LC<sub>50</sub>\*\* (rats) of >5000 mg/m<sup>3</sup> (4 hour exposure).

- **Naled** (dibrom) can be applied by truck-mounted or aircraft-mounted ULV sprayers at a maximum rate of 0.05 pounds (0.8 ounces) of active ingredient per acre by air and 0.33 ounce per acre by ground equipment. Naled is moderately toxic to humans and other mammals, and moderately to highly toxic to birds. It may also be moderately to highly toxic to fish and highly toxic to aquatic invertebrates and should not be applied over water with ground fogging equipment. Naled is highly toxic to honeybees and should not be applied at times and locations where bees are foraging. Naled is also highly corrosive and will damage the paint on cars or other objects that are too close to the sprayer.

Naled (e.g., Trumpet EC formulation\*) has an oral LD<sub>50</sub>\* (rats; female) of 180 mg/kg; a dermal LD<sub>50</sub>\* (rats; female) of 360 mg/kg, and an inhalation LC<sub>50</sub>\*\* (rats) of 1520 mg/m<sup>3</sup> (6 hour exposure).

**Pyrethroid Insecticides** - Due to their toxicity to fish, many of these products have restrictions which prohibit the direct application of these products to open water or within 100 feet of lakes streams, rivers or bays. Pyrethroids are also highly toxic to honeybees and care must be taken not to spray in areas and at times when honeybees are foraging.

- **Permethrin** can be applied by backpack, truck, or aircraft mounted foggers at a maximum rate of 0.0036 pounds (0.057 ounces) of active ingredient per acre. Some permethrin formulations are labeled for use as barrier treatments. Permethrin is practically non-toxic to birds and has a low mammalian toxicity. Permethrin is highly toxic to fish and aquatic invertebrates (crabs, mollusks) and should not be applied where surface water is present or where air movement favors drift towards aquatic environments. Permethrin is extremely toxic to honeybees and should not be applied at times and locations where bees are foraging.

Permethrin (e.g., Aqua-Resilin formulation\*) has an oral LD<sub>50</sub>\* (rats) of 1000 mg/kg; a dermal LD<sub>50</sub>\* (rabbits) of >5000 mg/kg, and an inhalation LC<sub>50</sub>\*\* (rats) of 2870 mg/m<sup>3</sup> (4 hour exposure).

- **Resmethrin** can be applied by backpack, truck, or aircraft mounted foggers at a maximum rate of 0.0035 pounds (0.056 ounces) of active ingredient per acre. Resmethrin is practically non-toxic to birds and has a low mammalian toxicity. Resmethrin is very is highly toxic to fish and aquatic invertebrates and should not be applied where surface water is present or where air movement favors drift towards aquatic environments. Resmethrin is highly toxic to honeybees and should not be applied at times and locations where bees are foraging.

Resmethrin (e.g., Scourge formulation\*) has an oral LD<sub>50</sub>\* (rats) of 2700 mg/kg; a dermal LD<sub>50</sub>\* (rabbits) of >2000 mg/kg, and an inhalation LC<sub>50</sub>\*\* (rats) of 2640 mg/m<sup>3</sup> (4 hour exposure).

- **Sumethrin** can be applied by backpack, truck, or aircraft mounted foggers at a maximum rate of 0.0036 pounds (0.057 ounces) of active ingredient per acre. Sumithrin has a moderate toxicity to aquatic invertebrates and is very highly toxic to fish and should not be applied where surface water is present or where air movement favors drift towards aquatic environments. Data on toxicity to birds and bees was unavailable.

Sumethrin (Anvil formulation\*) has an oral LD<sub>50</sub>\* (rats) of >5000 mg/kg; a dermal LD<sub>50</sub>\* (rabbits) of >2000 mg/kg, and an inhalation LC<sub>50</sub>\*\* (rats) of 4570 mg/m<sup>3</sup> (4 hour exposure).

- \* LD<sub>50</sub> = The lethal dosage of pesticide that would kill 50% of test animals (usually rats), expressed as milligrams of pesticide per kilogram of the animals body weight. The lower the value for an LD<sub>50</sub>, the more toxic the pesticide will be. The LD<sub>50</sub> for oral or dermal toxicity can vary from one insecticide formulation to another (e.g., two different formulations of the same insecticide could vary significantly, and pure technical grade material might be less toxic than some formulations of lower concentration). Although the effects of an insecticide would not be the same for humans as for rats, test rats are used as a rough equivalent for the pesticide's effects on mammals or humans. Translated to humans, an oral LD<sub>50</sub> of 5000 mg/kg (5 grams/kg) would mean that a human weighing roughly 100 kg (220 lbs) would have to consume 500 grams (1 pound) of pesticide to suffer a 50% mortality rate. An oral LD<sub>50</sub> of >5000 mg/kg is generally not considered to be very toxic. Table salt is not generally considered to be toxic, however, a 100 kg human who consumed 500 grams of table salt would suffer considerable or possibly lethal toxic effects.
- \*\* LC<sub>50</sub> = The lethal concentration of pesticide that would kill 50% of test animals (usually rats) after a specified amount of time breathing this concentration. The LC<sub>50</sub> for inhalation is usually expressed as milligrams of pesticide per cubic meter of air.

## **APPENDIX D**

### **Registered VA Pesticides for Mosquito Control**

*(Contained in electronic form on the attached Compact Disc)*

## APPENDIX E

### Pesticide Safety References

#### Product Labels and Material Safety Data Sheets for Mosquito Control Pesticides

Labels	Material Safety Data Sheets (MSDS)
<a href="#">ALT30DI</a> - Altosid Briquets - 30 Day	<a href="#">ALT30Dm</a> - Altosid Briquets - 30 Day
<a href="#">ALTPELI</a> - Altosid Pellets	<a href="#">ALTPELm</a> - Altosid Pellets
<a href="#">ALTSR20I</a> - Altosid Liquid Larvicide Concentrate - 20%	<a href="#">ALTSR20m</a> - Altosid Liquid Larvicide Concentrate - 20%
<a href="#">ALTSR5I</a> - Altosid Liquid Larvicide Concentrate - 5%	<a href="#">ALTSR5m</a> - Altosid Liquid Larvicide Concentrate - 5%
<a href="#">ALTXRGI</a> - Altosid Extended Residual Granular	<a href="#">ALTXRGm</a> - Altosid Extended Residual Granular
<a href="#">ALTXRl</a> - Altosid XR Extended Residual Briquets 150 Day Briquets 150 Day Teknar HP-D Larvicide HP-D Larvicide	<a href="#">Per 3030m</a> - Permanone 30-30
<a href="#">3030I</a> - Permanone 30-30	<a href="#">ALRXRm</a> - Altosid XR Extended Residual
<a href="#">Tekl</a> - Teknar HP-D Larvicide	<a href="#">Tekm</a> - Teknar HP-D Larvicide
<a href="#">Teknar_g</a> - Teknar G (Biological Larvicide Granules) Teknar G (Biological Larvicide Granules)	<a href="#">Trum</a> - Trumpet EC - Insecticide
<a href="#">Trul</a> - Trumpet EC - Insecticide	<a href="#">Veclxm</a> - VectoLex CG (Biological Larvicide Granules)
<a href="#">Veclxl</a> - VectoLex CG (Biological Larvicide Granules)	<a href="#">Veclxwdgm</a> - VectoLex WDG (Biological Larvicide)
<a href="#">Veclxwdgl</a> - VectoLex WDG (Biological Larvicide)	<a href="#">Anvil10 +10 msds</a> - Anvil 10+10 ULV
<a href="#">Anvil10+10I</a> - Anvil 10+10 ULV	

<http://www.mda.state.md.us/mosquito/msdslabel.htm>

ABBOTT LABORATORIES

**VectoLex<sup>®</sup> CG**

## Material Safety Data Sheet

Abbott Laboratories, Inc.  
Chemical & Agricultural Products Division  
North Chicago, IL 60064-6316  
Emergency Telephone: 1-800-323-9597  
Chemtrec: 1-800-424-9300

**Issue Date:** 06/17/99  
**List/Code:** 5722/16025  
**DOT Classification:** Not Regulated  
**EPA Registration No.:** 275-77  
**Emergency Overview:** This material may be a skin or eye irritant.  
**NFPA:** Health - 0; Fire - 1; Reactivity - 0

### COMPOSITION / INGREDIENTS

Ingredient Name:	<i>Bacillus sphaericus</i> Serotype (H-5a5b), strain 2362	Inert Ingredients*
Concentration %:	7.5%	92.5%
CAS/RTECS Numbers:	N/A / N/A	N/A / N/A
OSHA-PEL 8HR TWA:	N/L	N/L
STEL:	N/L	N/L
Ceiling:	N/L	N/L
ACGIH-TLV 8HR TWA:	N/L	N/L
STEL:	N/L	N/L
Ceiling:	N/L	N/L
OTHER 8HR TWA:	N/A	N/A
LIMITS STEL:	N/A	N/A
Ceiling:	N/A	N/A

\* Identity withheld as a Trade Secret

### HEALTH CONSIDERATIONS

<b>Route(s) of Entry:</b>	Skin: N/D    Inhalation: N/D    Ingestion: N/D
<b>Carcinogenicity Rating:</b>	NTP: N/L    IARC: N/L    OSHA: N/L    ACGIH: N/L    None
<b>Signs and Symptoms:</b>	N/D. Data suggest mild skin or eye irritation.
<b>Medical Conditions Aggravated by Exposure:</b>	N/D. Data suggest pre-existing skin or eye lesions.
<b>Oral Toxicity:</b>	N/D. LD50 > 5,000 mg/kg in rats for <i>Bacillus sphaericus</i> Technical Powder.
<b>Dermal Toxicity:</b>	N/D. LD50 > 2,000 mg/kg in rabbits for <i>Bacillus sphaericus</i> Technical Powder.
<b>Inhalation Toxicity:</b>	N/D. <i>Bacillus sphaericus</i> Technical Powder was not lethal in an inhalation study at the maximum attainable concentration of 0.09 mg/ltr/4 hours.
<b>Corrosiveness:</b>	N/D
<b>Dermal Irritation:</b>	Mildly irritating in a skin irritation test in rabbits; two animals with slight redness at 24 hours.
<b>Ocular Irritation:</b>	Mild to moderate redness with mild swelling and slight discharge in an eye irritation test in rabbits.
<b>Dermal Sensitization:</b>	N/D
<b>Target Organs:</b>	N/D
<b>Special Target Organ Effects:</b>	N/D
<b>Carcinogenicity Information:</b>	N/D

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## **VectoLex® CG**

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### **EMERGENCY AND FIRST AID PROCEDURE**

**Eyes/Skin:** Remove from source of exposure. Flush with copious amounts of water. If irritation persists or signs of toxicity occur, seek medical attention. Provide symptomatic/supportive care as necessary.

**Ingestion/**

**Inhalation:** Remove from source of exposure. If signs of toxicity occur, seek medical attention. Provide symptomatic/supportive care as necessary.

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### **FIRE FIGHTING PROCEDURES**

<b>Flash Point:</b>	N/A
<b>Lower Explosive Limit (%):</b>	N/D
<b>Upper Explosive Limit (%):</b>	N/D
<b>Autoignition Temperature:</b>	N/D
<b>Fire and Explosive Hazards:</b>	N/D
<b>Extinguishing Media:</b>	Use appropriate medium for underlying cause of fire.
<b>Fire Fighting Instructions:</b>	Wear protective clothing and self-contained breathing apparatus.

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### **SAFE HANDLING, USE, STORAGE, and DISPOSAL**

<b>Handling:</b>	N/D
<b>Storage:</b>	Store in cool, dry place.
<b>Special Precautions:</b>	Wash thoroughly with soap and water after handling.
<b>Spill or Release Procedures:</b>	Recover product, place into appropriate container for disposal. Avoid dust. Ventilate and wash spill area.
<b>Disposal:</b>	Dispose in accordance with state, local and federal regulations.

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## **VectoLex® CG**

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### **PHYSICAL AND CHEMICAL PROPERTIES**

<b>Appearance/Physical State:</b>	Granules
<b>Odor:</b>	Characteristic Odor
<b>Boiling Point:</b>	N/A
<b>Melting/Freezing Point:</b>	N/A
<b>Vapor Pressure (mm Hg):</b>	N/A
<b>Vapor Density (Air=1):</b>	N/A
<b>Evaporation Rate:</b>	N/D
<b>Bulk Density:</b>	N/A
<b>Specific Gravity:</b>	N/D
<b>Solubility:</b>	Partially suspends/soluble in water
<b>pH:</b>	N/A
<b>Viscosity:</b>	N/A

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Date issued: October, 1997

Supersedes: April, 1996

## MATERIAL SAFETY DATA SHEET - ZOECON® ALTOSID® LIQUID LARVICIDE CONCENTRATE

**Manufacturer:** Wellmark International

Address: 1000 Tower Lane, Suite 245, Bensenville, Illinois 60106

Emergency Phone: 1-800-248-7763

**Transportation Emergency Phone:** CHEMTREC: 1-800-424-9300

### 1. CHEMICAL PRODUCT INFORMATION

Product Name: Zoecon® Altosid® liquid larvicide Concentrate

Chemical Name/Synonym: (S)-Methoprene; isopropyl (2E,4E,7S)-11-methoxy-3,7,11-trimethyl-2,4-dodecadienoate

Chemical Family: Terpenoid

Formula: C<sub>19</sub>H<sub>34</sub>O<sub>3</sub>

EPA Registration No.: 2724-446

RF Number: 437

### 2. COMPOSITION/INFORMATION ON INGREDIENTS

Component (chemical, common name)	NA S m b e r	Weight	Tolerance
(S)-Methoprene: isopropyl (2E,4E,7S)-11-methoxy-3,7,11-trimethyl-2,4-dodecadienoate	65733-16-6	20.0%	Not established
Inert ingredients (non-hazardous and/or trade secret)		80.0%	N/A

### 3. HAZARD INFORMATION

#### PRECAUTIONARY STATEMENT

**CAUTION:** CAUSES MODERATE EYE IRRITATION. AVOID CONTACT WITH EYES OR CLOTHING. WASH THOROUGHLY WITH SOAP AND WATER AFTER HANDLING. PROLONGED OR FREQUENTLY REPEATED SKIN CONTACT MAY CAUSE ALLERGIC REACTIONS IN SOME INDIVIDUALS.

SIGNS AND SYMPTOMS OF **OVEREXPOSURE:** No adverse reactions have resulted from normal human exposure during research and testing.

PRIMARY ROUTE OF ENTRY **Dermal/Eye:** Yes **Oral:** No **Inhalation:** No

ACUTE TOXICITY

**Oral:** LD<sub>50</sub> (rat): >5,000 mg/kg (highest dose tested) (HDT)  
(Based on (S)-Methoprene)

**Dermal:** LD<sub>50</sub> (rabbit): >2,000 mg/kg (highest dose tested) (HDT)  
(Based on (S)-Methoprene)

**Inhalation:** LC<sub>50</sub> (rat): >5.2 mg/L air (4 hour study)

OTHER TOXICOLOGICAL INFORMATION

**Skin Irritation:** Non-irritating (rabbit)  
(Based on (S)-Methoprene)

**Eye Irritation:** Practically non-irritating (rabbit)  
(Based on (S)-Methoprene)

**Sensitizer:** Not a sensitizer (guinea pig)  
(Based on (RS)-Methoprene)

**Eye:** Immediately flush with copious amounts of water for at least 15 minutes. See a physician if irritation persists.

**Skin:** Wash material off with copious amounts of water and soap. Remove contaminated clothing and footwear. See a physician if symptoms persist.

**Ingestion:** Drink 1-2 glasses of water and try to induce vomiting. Seek medical attention. Never give anything by mouth to an unconscious person.

**Inhalation:** Remove victim to fresh air. See a physician if cough or other respiratory symptoms develop.

Note to Physician: Treat symptomatically

### 5. FIRE FIGHTING MEASURES

NFPA Rating: **Health:** 0 **Fire:** 0 **Reactivity:** 0

Flammability Class: Combustible liquid

Flask Point: Does not flash

Explosive limits (% of Volume): None

**Extinguishing Media:** Water, Foam, CO<sub>2</sub>

**Special Protective Equipment:** Firefighters should wear full protective clothing and self-contained breathing apparatus.

**Fire Fighting Procedures:** Normal procedures. Do not allow fire fighting water to escape into waterways or sewers.

**Combustion Products:** Carbon monoxide, carbon dioxide

**Unusual Fire/Explosion Hazards:** None

### 6. ACCIDENTAL RELEASE MEASURES

**Steps to be Taken:** In case of leakage or spill, soak up with absorbent material. Place in a container for disposal.

**Absorbents:** Clay granules, sawdust, dirt or equivalent.

**Incompatibles:** None

## 7. HANDLING AND STORAGE

**Handling:** Avoid contact with eyes or clothing. Wash thoroughly with soap and water after handling.

**Storage:** Store in a cool, dry place, away from other pesticides, food and feed.

## 8. EXPOSURE CONTROL/PERSONAL MEASURES

**Exposure Limits:** Not established

**Ventilation:** Use with adequate ventilation.

**Personal Protective Equipment:** Under ordinary use conditions, no special protection is required. If prolonged exposure is expected, it is recommended to wear a MSHA/NIOSH approved organic vapor/Pesticide respirator, impervious gloves, chemical goggles or safety glasses with side shields.

## 9. PHYSICAL AND CHEMICAL PROPERTIES

**Appearance and Odor:** Creamy, yellow liquid with slight odor.

**Boiling Point:** 100°C

**Melting Point:** Not applicable

**Vapor Pressure (mm Hg):** 17.5 mm Hg

**Vapor Density (Air = 1):** 0.6 (water phase)

**Specific Gravity:** 1.04 1.06

**Bulk Density:** 8.3 lbs/gal

**Solubility:** Disperses in water

**Evaporation Rate:** Approximately 0.8

**pH:** 7.5

**Stability:** Stable

**Reactivity:** Non-reactive

**Incompatibility with**

**Other Materials:** Bleach, oxidizing/alkaline materials

**Decomposition Products:** None

**Hazardous Polymerization:** Will not occur

### NOTES

### CHRONIC TOXICITY [Based on (RS)-Methoprene]

Methoprene is not considered as an oncogenic compound. The NOEL for noncarcinogenic effects in an 18 month mouse study was 250 ppm.

### DEVELOPMENTAL/REPRODUCTIVE TOXICITY [Based on (RS)-Methoprene]

Methoprene is not a teratogenic compound. The NOEL for maternal and embryotoxicity in rabbits was 200 mg/kg/day. The NOEL for reproductive effects in rats was 500 ppm.

### MUTAGENICITY [Based on (RS)-Methoprene]

Methoprene is not a mutagenic compound.

## 12. ECOLOGICAL INFORMATION

### ENVIRONMENTAL FATE [Based on (RS)-Methoprene]

**Hydrolysis:** T<sub>1/2</sub> > 4 weeks

**Photolysis:** T<sub>1/2</sub> < 10 hours

**Soil half life:** ~10 days

**Water solubility:** < 2 ppm

### ECOTOXICITY [Based on (S)-Methoprene]

**Acute Toxicity:** fish: LC<sub>50</sub> (trout): 760 ppb, (bluegill): >370 ppb  
aquatic invertebrates: LC<sub>50</sub> (Daphnia): 360 ppb

## 13. DISPOSAL CONSIDERATIONS

Wastes resulting from this product may be disposed of on site or at an approved waste management facility. Triple rinse (or equivalent). Then offer for recycling or reconditioning, or puncture and dispose of in a sanitary landfill, or incineration, or if allowed by state and local authorities, by burning. If burned, stay out of smoke.

**DOT49CFR Description:** Not regulated as hazardous by D.O.T.

**Freight Classification:** Insecticides, NQI other than poison in boxes or drums. NMFC 102120

## 15. REGULATORY INFORMATION

**CERCLA (Superfund):** Not regulated

**RCRA:** Not regulated as hazardous

**SARA 311/312 HAZARD CATEGORIES**

**Immediate Health:** Yes (irritation)

**Delayed Health:** No

**Fire:** No

**Sudden Pressure:** No

**Reactivity:** No

The information presented herein, while not guaranteed, was prepared by technically knowledgeable personnel and to the best of our knowledge is true and accurate. It is not intended to be all inclusive and the manner and conditions of use and handling may involve other or additional considerations.

# **APPENDIX F**

## **EDRC Technical Note C-20**

### **Implementation Guidance for the Control of Undesirable Vegetation on Dredged Material**